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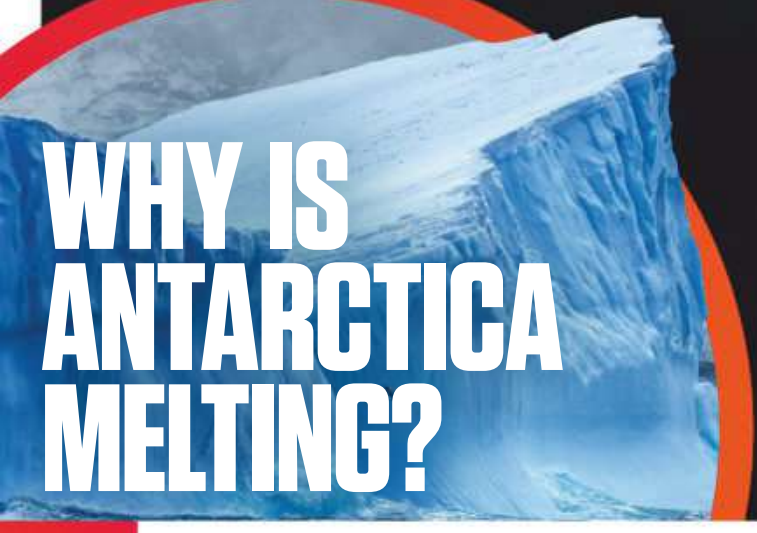

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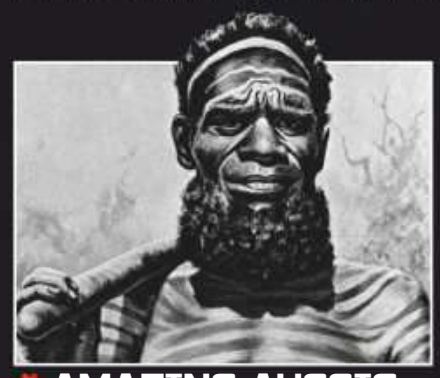

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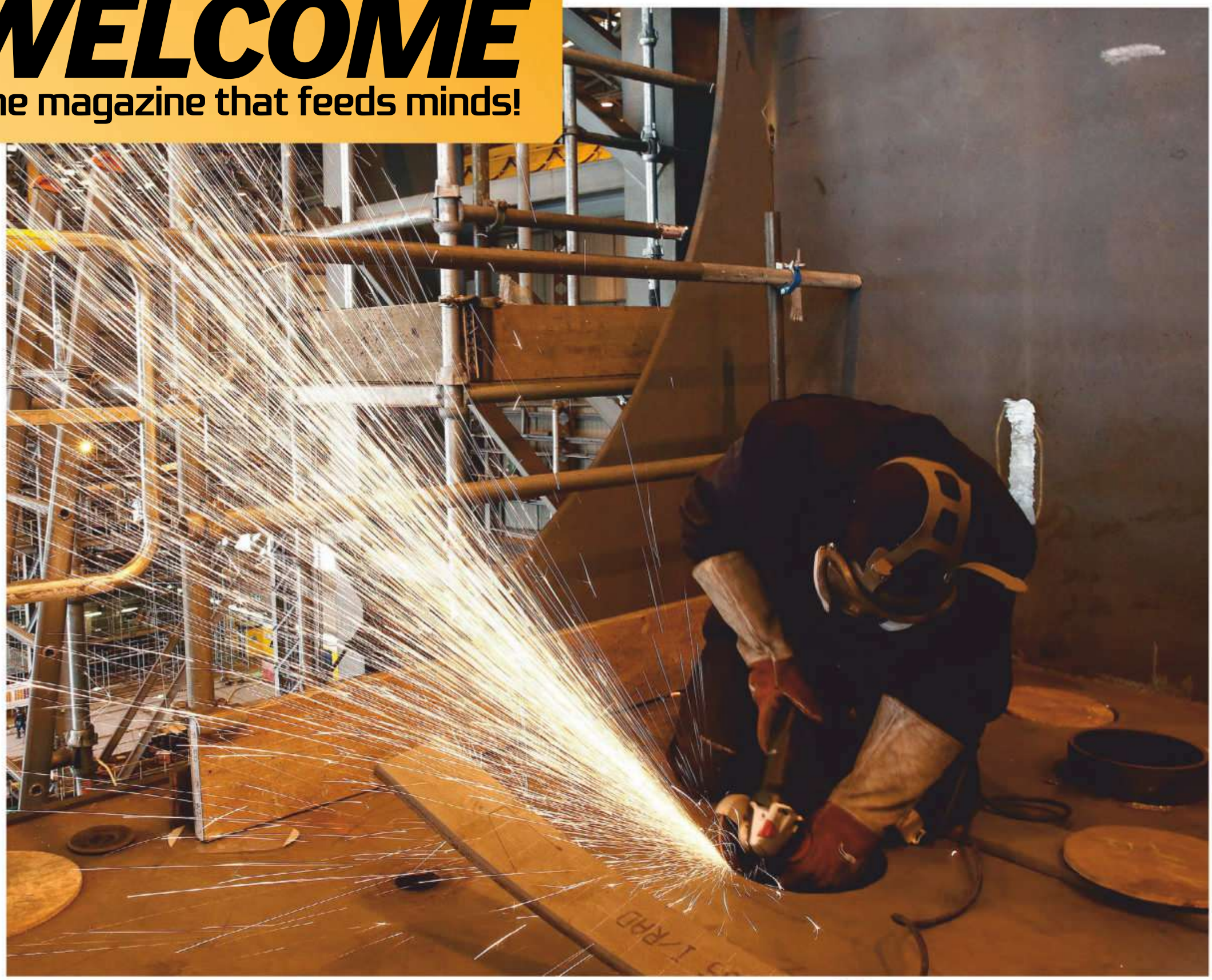

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"It'll be an essential component of the Royal Navy fleet into the 2060s"

How to build a warship, page 22

t's not as if you can stroll down to your local boat dealership and pick up an armoured combat vessel from the harbour on a whim. So when the Royal Navy wants to update its fleet to include the most advanced warships in the world, they have to commission the construction of the entire thing from scratch. In this issue of **How It Works**, we've explored the Scottish dry dock where HMS Glasgow, the Royal Navy's first Type-26 frigate, is being built. Discover how the ship is painstakingly assembled, the impressive hardware on board and its multi-mission capabilities that include defending the fleet from submarines and disaster relief. Enjoy the issue!

Ben Editor

Meet the team...

Nikole
Production Editor
We're familiar with how the world looks on paper today, but this wasn't always the case. Explore the most ancient maps on page 60.

Scott
Staff Writer
Did you know that smartphone cameras came from space travel? Discover how space technology benefits Earth on page 44.

Baljeet
Research Editor
See the tech inside the nuclear-powered vessels used to break through the thick Arctic ice to access the ocean on page 32.

Duncan
Senior Art Editor
Our cells make up everything in our bodies, and each has specific functions to keep us – and itself – alive. Learn more on page 58.

Ailsa
Staff Writer
Discover the ancient medicinal knowledge of Australia's plants and animals that's still being used today on page 34.

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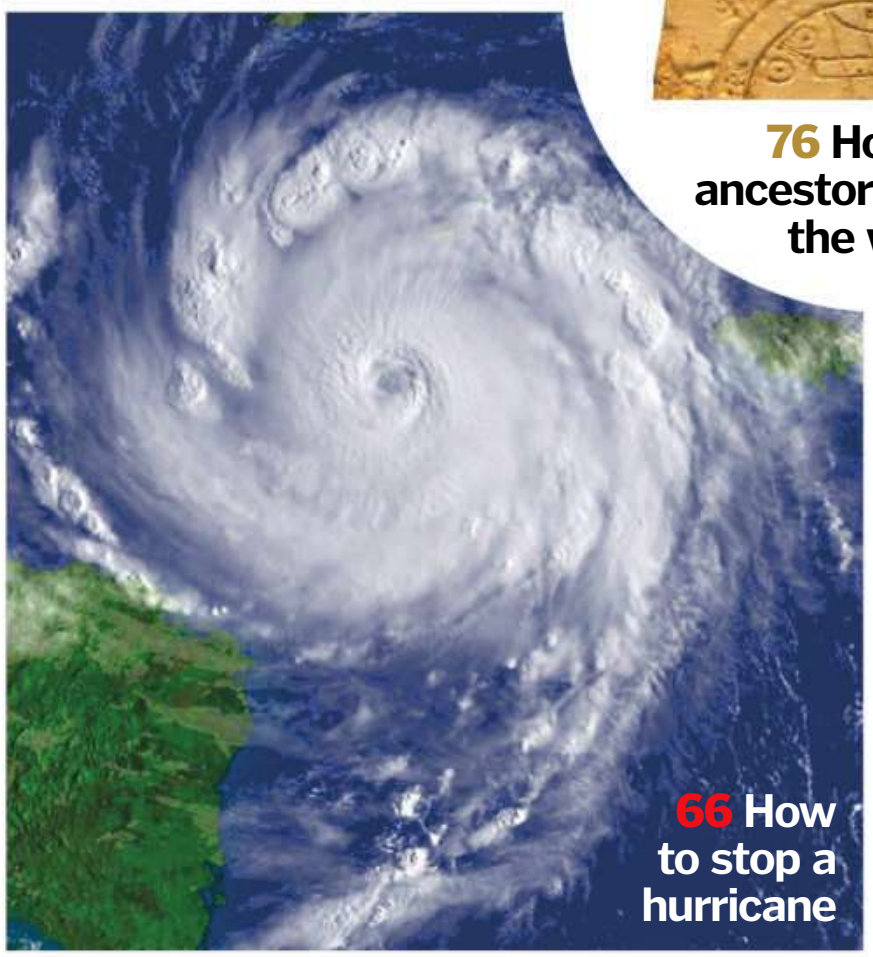

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AR ZONE!

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When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

HOW THE AUGMENTED REALITY WORKS

After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented-reality 3D image we've previously uploaded on your screen.

GROWING NERVE CELLS

This group of cells, known as multipotent human neural progenitor cells, transform into the many different cells that form the human nervous system, such as star-shaped astrocyte cells. The cells in this image were artificially cultured under conditions similar to those in the developing brain, and after three weeks they were stained. The green cells are neural progenitor cells and the others, seen in orange, are astrocyte cells. Both sport nuclei that are coloured blue. Over time, most – if not all – of the neural progenitor cells will diversify into astrocyte cells. This photomicrograph image was taken at 200x magnification.

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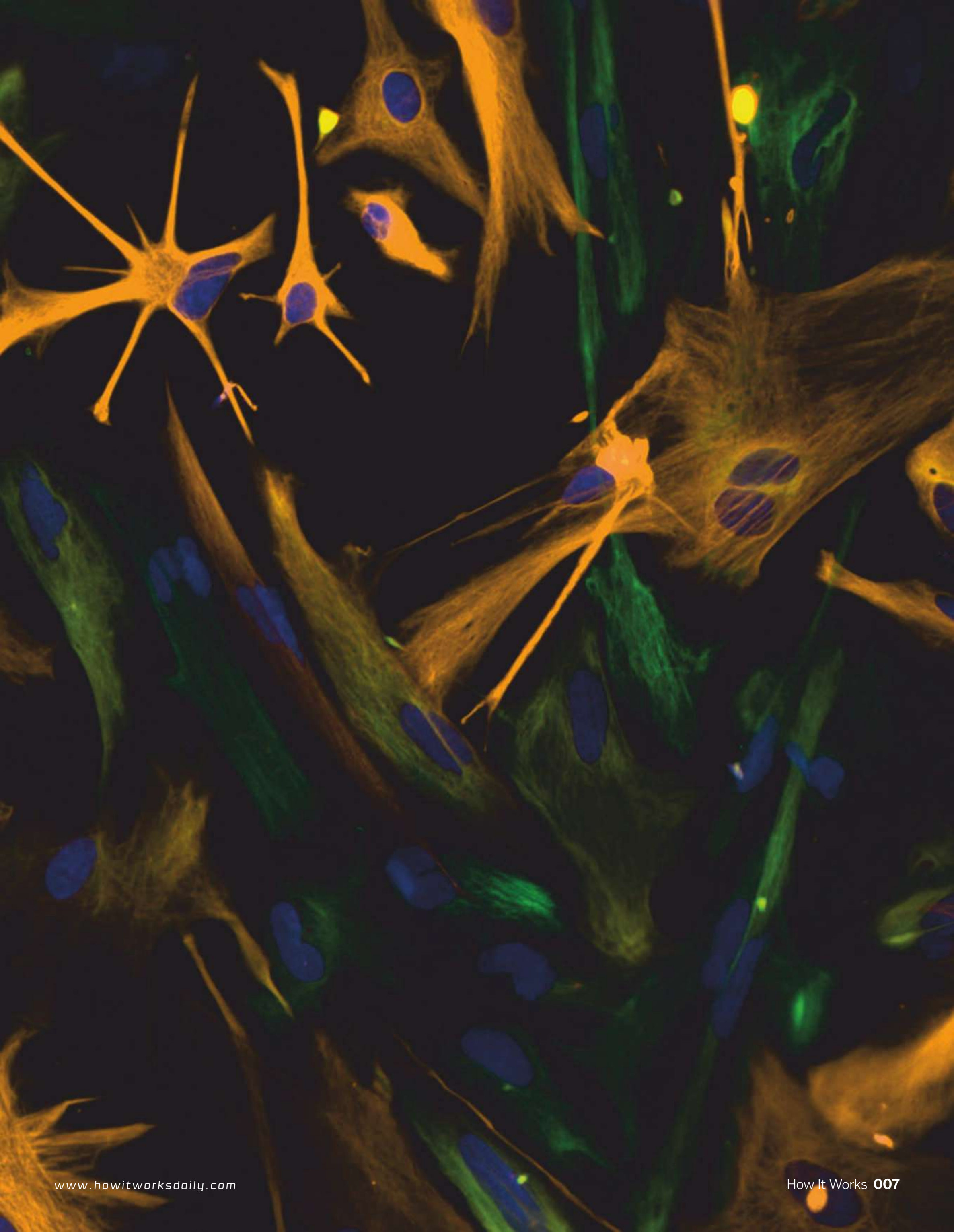

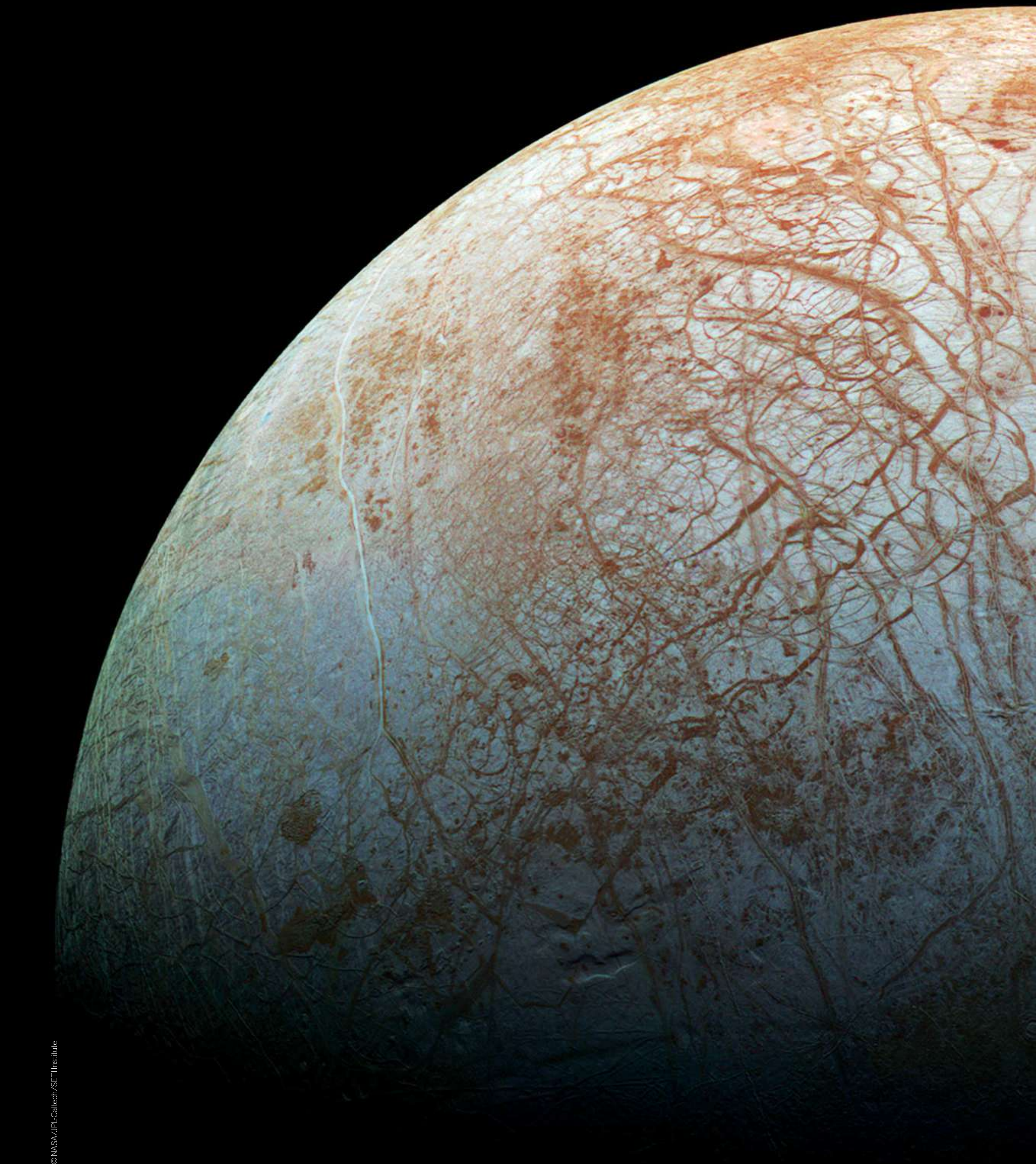

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EUROPA'S FROZEN SURFACE

Meet Jupiter's icy moon, Europa. It's the gas giant's sixth-closest moon and is one of the coldest places in the Solar System, reaching temperatures of no more than -160 degrees Celsius at its equator and plummeting below -220 degrees Celsius at its poles. This image was taken by NASA's Galileo spacecraft in the late 1990s and highlights the many long, linear cracks and ridges on its surface, seen in reddish-brown. The white expanses around the ridges are most likely pure water ice, which scientists believe forms a shell 10 to 15 miles thick and floats on an ocean up to 100 miles deep.

GLOWING MUSHROOMS

During the day these mushrooms are unimpressive, but when darkness falls they light up. Ghost fungi (*Omphalotus nidiformis*) are large mushrooms that grow in Australia and give off a radioactive-green bioluminescent glow at night. These fungi produce a chemical called luciferin that undergoes a chemical reaction, which releases energy in the form of green light. It's been suggested that the glow serves as a lure for spore-spreading insects. However, a conclusive answer is yet to be found. Bioluminescent fungi aren't a recent discovery, having been described in documents written by the ancient Greek philosopher Aristotle.

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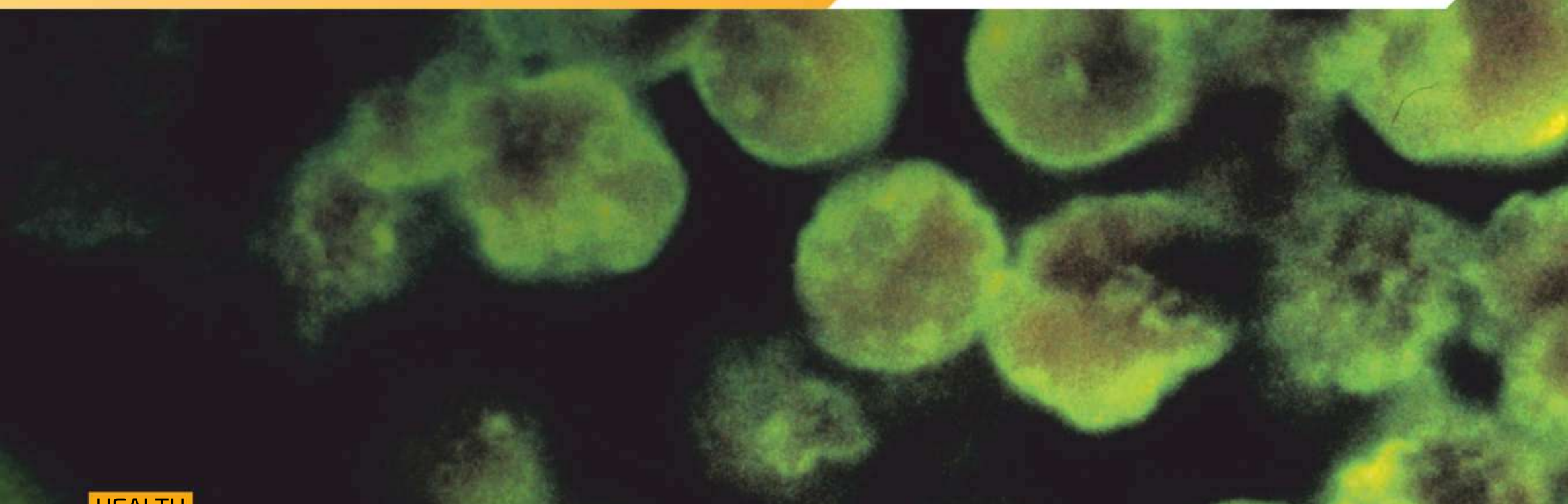


HEALTH

Brain-eating amoebae on the move

Words by **Rachael Rettner**

Deadly 'brain-eating' amoeba infections have historically occurred in the Southern United States, but cases have been appearing farther north in recent years, and it's likely because of climate change. Researchers from the Centers for Disease Control and Prevention (CDC) examined cases of this brain-eating amoeba, known as *Naegleria fowleri*, over a four-decade period in the US. They found that although the number of cases that occur each year has remained about the same, the geographic range of these cases has been shifting northward, with more cases popping up in Midwestern states than before.

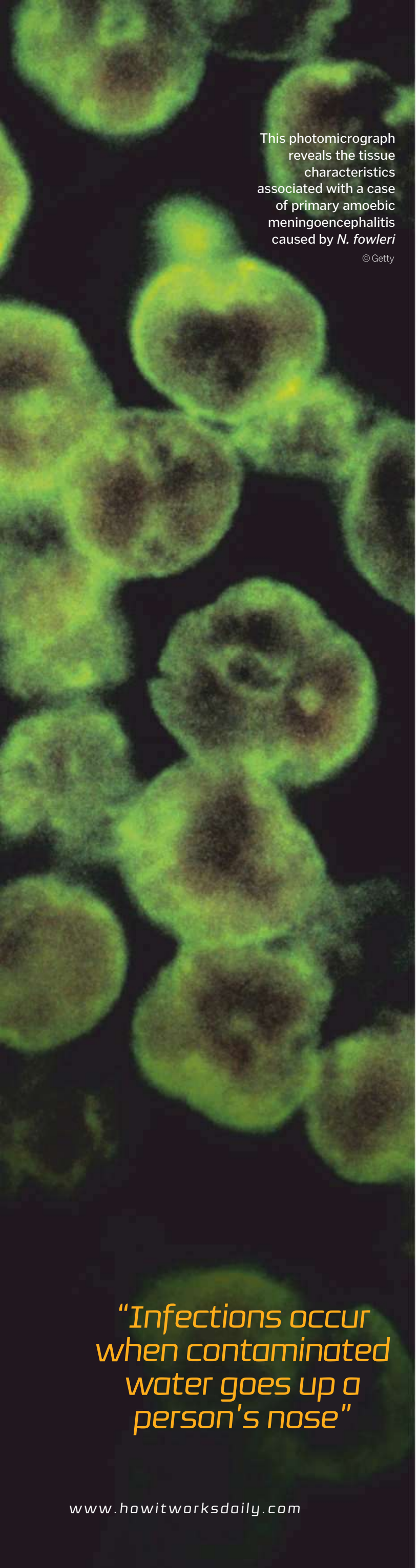
N. fowleri is a single-celled organism that's naturally found in warm freshwater, such as lakes and rivers. It causes a devastating brain infection known as primary amoebic meningoencephalitis (PAM), which is almost universally fatal. Infections occur when contaminated water goes up a person's nose, allowing the organism to enter the brain through the olfactory nerves – responsible for your sense of smell – and destroy brain tissue. Swallowing contaminated water will not cause an infection.

Because *N. fowleri* thrives in warm waters – up to 45 degrees Celsius – it's possible that warming global temperatures may affect the organisms' geographic range. Researchers analysed US cases of *N. fowleri* linked to recreational water exposure, such as swimming in lakes, ponds, rivers or reservoirs, from 1978 to 2018. They identified a total of 85 cases of *N. fowleri* that met their criteria for the study – cases that were tied to recreational water exposure and included location data, for example.

During this time, the number of yearly reported cases was fairly constant, ranging from zero to six per year. The vast majority of cases, 74, occurred in Southern states, but six were reported in the Midwest, including Minnesota, Kansas and Indiana. Of these six cases, five occurred after 2010.

What's more, researchers using a model to examine trends in the maximum latitude of cases per year found that the maximum latitude had shifted about 8.2 miles northward per year during their study period. The researchers also analysed weather data from around the date each case occurred, finding that, on average, daily temperatures in the two weeks leading up to each case were higher than the historical average for each location. "It is possible that rising temperatures and consequent increases in recreational water use, such as swimming and water sports, could contribute to the changing epidemiology of PAM," the researchers stated.

Efforts to characterise PAM cases, such as knowing when and where these cases occur and being aware of changes in their geographic range, could help predict when it's riskiest to visit natural swimming holes. Since there is no rapid test for *N. fowleri* in water, the only sure way to prevent these infections is to avoid swimming in warm freshwater. If you choose to go swimming in warm freshwater, you can try to avoid having water go up your nose by holding your nose closed, using nose clips or keeping your head above water.



This photomicrograph reveals the tissue characteristics associated with a case of primary amoebic meningoencephalitis caused by *N. fowleri*

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"Infections occur when contaminated water goes up a person's nose"

The Australian Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Australia Telescope National Facility (ATNF) hosts the Parkes Observatory radio telescope

© Getty

SPACE & PHYSICS

Alien hunters detect mystery signal

Words by **Rafi Letzter**

Astronomers hunting for radio signals from alien civilisations have detected an 'intriguing' signal from the direction of Proxima Centauri, the nearest star system to the Sun at just over four light years away. Researchers are still investigating the discovery, and the data has not been made public, but the signal is reportedly a narrow beam of 980 MHz radio waves detected in April and May 2019 by the Parkes telescope in Australia.

The Parkes telescope forms part of the Breakthrough Listen project to hunt for radio signals from technological sources beyond the Solar System. The 980 MHz signal appeared once and was never detected again. That frequency is important because that band of radio waves is typically lacking signals from human-made craft and satellites.

Breakthrough Listen detects unusual radio signals all the time. Between Earthly sources, the Sun's natural radio output and natural sources beyond the Solar System, there are a lot of radio waves bouncing around out there. But this signal appears to have come directly from the Proxima Centauri system, just 4.2 light years from Earth. Even more tantalising, the signal reportedly shifted slightly while it was being observed in a way that resembled the shift caused by the movement of a planet. Proxima Centauri has one known rocky world 17 per cent larger than Earth, and one known gas giant.

The Guardian has quoted an unnamed source with apparent access to the data on this signal as saying: "It is the first serious candidate for an alien communication since the 'Wow! signal,'" a famous radio signal detected in 1977 that also resembled a technosignature. But *The Guardian* cautioned that this signal is "likely to have a mundane origin too". Such mundane sources include a comet or its hydrogen cloud, which could also explain the Wow! signal.

Penn State University's Sofia Sheikh, who led the analysis of the signal for Breakthrough Listen, voiced her excitement about it: "It's the most exciting signal that we've found in the Breakthrough Listen project because we haven't had a signal jump through this many of our filters before," Sheikh explained, adding that the signal is now being referred to as Breakthrough Listen Candidate 1, or BLC1.

An inherent challenge in searching for alien communications is that no one knows how aliens might communicate, and no one knows all the potential natural sources of radio waves in the universe. When signals arrive that seem even plausibly technological and don't come with easy natural explanations, it's tempting to make the jump to aliens. So far, no data on this signal is public, and it's likely that even when it does become public there will be no conclusive answers… that's what happened with the Wow! signal after all.

IN ASSOCIATION WITH LIVESCIENCE

ANIMALS

New fungi turns flies into zombies before eating them from the inside

Words by **Stephanie Pappas**

Two newly discovered fungi species have a similarly macabre mode of action: they eat flies alive while using them to drop spores on new victims. The related species, *Strongwellsea tigrinae* and *Strongwellsea acerosa*, attack the fly species *Coenosia tigrina* and *Coenosia testacea*, which look like ordinary house flies but undergo a horrific change once they're invaded by the fungi. The fungi eat one or more holes in the abdomens of the flies and then produce clumps of orange spores, which spread by dropping out of the holes.

The infected, now-zombified flies remain alive for days during this process, meaning they inadvertently spread the spores far and wide, particularly when mating with other flies. Meanwhile, the fungi continue to devour the flies alive. Finally, the fungi-ravaged insects collapse to the ground in spasms and die. Even after death the flies can spread the spores of their killers: the flies' abdomens gradually crumble, releasing more spores from inside. These spores have thick walls that may help them lie dormant over winter, infecting more flies when the insects become active in the spring.

Danish researchers discovered dozens of fungi-infected flies during fieldwork in Jægerspris and Amager, Denmark. The flies were found in both rural areas and residential neighbourhoods, hinting of a horror-story struggle playing out in seemingly peaceful fields and yards. "This is an exciting and bizarre aspect of biodiversity that we have discovered in Denmark,"said Jørgen Eilenberg, a biologist at the University of Copenhagen. "In and of itself, this mapping of new and unknown biodiversity is valuable. But at the same time this is basic new knowledge that can serve as a basis for experimental studies of infection pathways and the bioactive substances involved."

Eilenberg and his colleagues suspect that the fungi 'dope' the flies with some substance that keeps them flying and active even as their abdomens are devoured from the inside out. Other fungi that prey on insects use amphetamine-type substances to keep their victims moving, so perhaps the newly discovered fungi do the same, Eilenberg said. The fungi might also produce antimicrobial substances that keep other pathogens away from the abdomen holes in order to keep the flies alive longer.

"We would definitely like to continue our research, as doing so has the potential to discover – and later make use of – these substances, perhaps in medicine," Eilenberg said.

The fly species *Coenosia tigrina* was infected with the fungus *Strongwellsea tigrinae*, which ripped holes into the fly's abdomen

"They eat flies alive while using them to drop spores on new victims"

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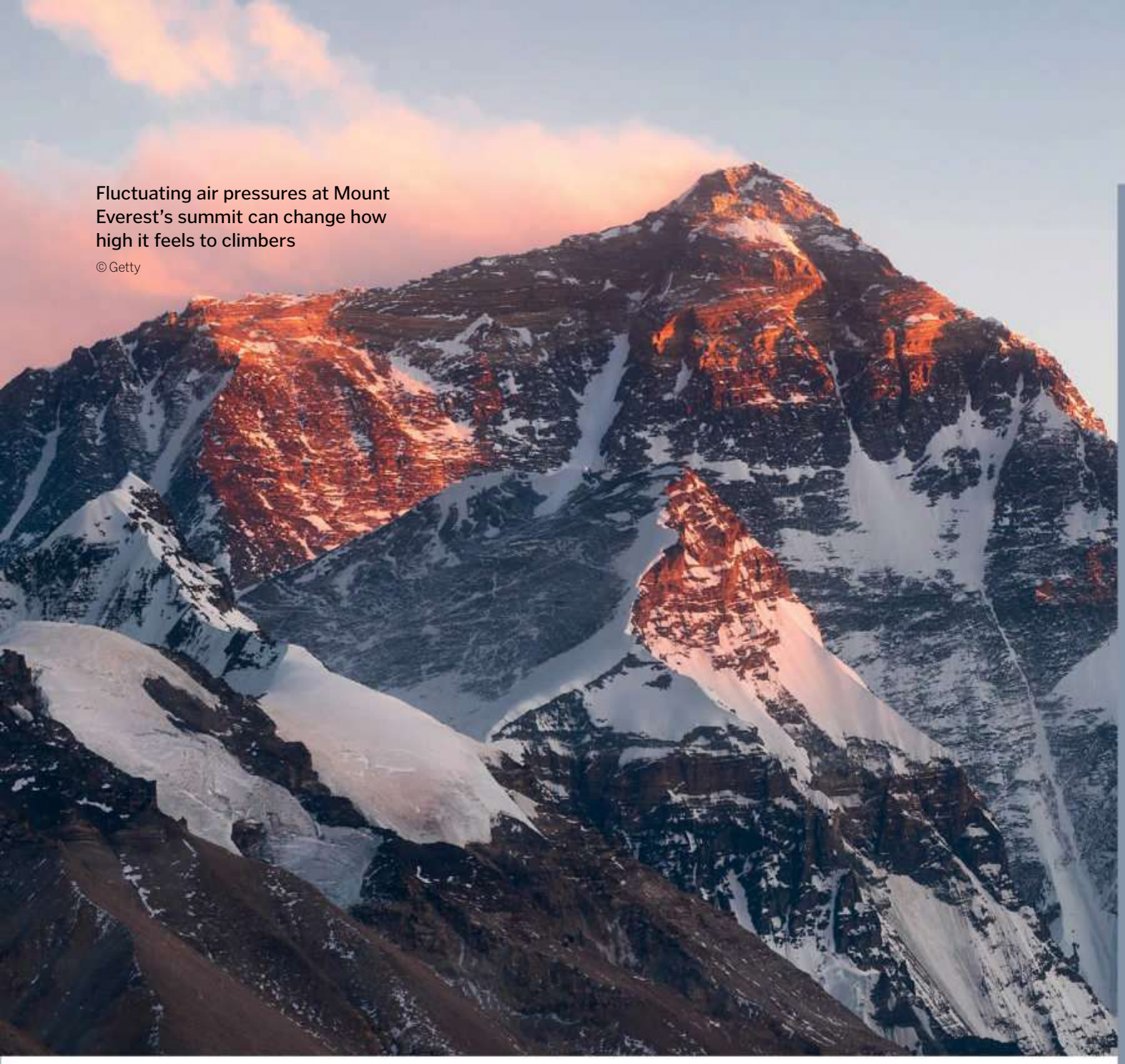


Fluctuating air pressures at Mount Everest's summit can change how high it feels to climbers

© Getty

PLANET EARTH

Air pressure makes Everest 'shrink'

Words by **Brandon Specktor**

Mount Everest is the tallest mountain in the world at almost 8,849 metres above sea level, but sometimes it feels like the second tallest. That's because the mountain's air pressure fluctuates significantly throughout the year, a recent study found, causing the summit's 'perceived elevation' to occasionally dip below that of its less lofty rival K2, the second-tallest mountain in the world.

"Sometimes K2 is higher than Everest," Tom Matthews, a climate scientist at Loughborough University in the United Kingdom, said. Matthews and his colleagues looked at more than 40 years of air pressure data recorded by both weather stations near the summit of Mount Everest and the European Space Agency's Copernicus satellite.

Air pressure is closely tied to oxygen availability on Everest; when air pressure decreases, there are fewer oxygen molecules in the air, making the simple act of breathing much more strenuous. For this reason, many who choose to hike Everest rely on supplemental oxygen to stay on their feet as they scale to higher elevations where the air is thinner.

But while air pressure reliably decreases with elevation, it also fluctuates with the weather. From 1979 to 2019, the air pressure near the peak of Everest ranged anywhere from 309 to 343 hectopascals, roughly one-third the pressure at sea level, depending on the season.

The oxygen availability on Everest makes the mountain feel thousands of metres shorter than it really is. Occasionally the 8,848.86-metre mountain feels shorter – to our bodies, at least – than the world's next tallest mountain, K2, which measures 8,611 metres tall.

The researchers also found that air pressure on Everest was consistently highest in the summertime, making that the best season to scale the mountain based purely on oxygen availability. As Earth's atmosphere continues to warm due to climate change, there could even be a permanent decrease in the mountain's perceived elevation. "Warming will shrink the mountain a little bit," Matthews said.

SPACE & PHYSICS

An angel, devil and a heart appear on Mars

Words by **Brandon Specktor**

It's summer at the south pole of Mars, and the angels and devils are coming out to play. You can see them both in a stunning image of its thawed pole, taken by the European Space Agency (ESA). The devils, it should be said, are made of dust. Just like on Earth, Martian dust devils form when a pocket of warm air suddenly rises through a column of cool air, creating a spinning updraft. Unlike on Earth, however, these dusty cyclones can tower six miles high. You can see the tracks of one such cyclone in the dark region to the far left of the image below.

And as for the angel? For an explanation, we'll have to turn to the heavens. Take a close look at the 'halo' around the angel's head, and you'll notice the steep, sloping walls of an impact crater. This ethereal feature is the product of a meteorite collision that dug deep into the Red Planet's crust, building a crater and revealing the layers of ancient sediment below.

Those old layers take on a dark-red hue and are visible in this image all through the angel's body, as well as the heart-shaped structure below its right wing. What this reddish stuff is made of, though scientists aren't sure. These strange, dark deposits are found all over Mars and are thought to be the result of ancient volcanic activity long buried below the Martian crust. Erosion, asteroid impacts, scathing and speedy winds and dust storms have slowly brought these mysterious red scars to the surface.

© ESA

An angel-like province of red sediment has appeared near the south pole of Mars – but what caused it?

IN ASSOCIATION WITH LIVESCIENCE

PLANET EARTH

Arctic methane could be unlocked by the Moon

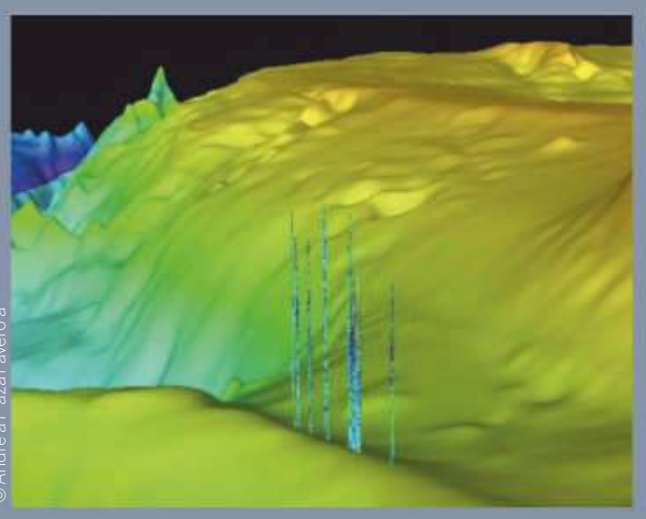
Words by **Patrick Pester**

The Moon could be affecting how much methane is released from the Arctic Ocean seafloor. The tides, controlled by the Moon, affect how much methane is released from seafloor sediments. Low tides mean less pressure and more methane released, while high tides create more pressure, and therefore less methane emission.

The research was conducted in the west Svalbard region of the Arctic. "It is the first time that this observation has been made in the Arctic Ocean. It means that slight pressure changes can release significant amounts of methane," said Jochen Knies, a marine geologist at the Centre for Arctic Gas Hydrate, Environment and Climate.

Methane contributes to global warming by trapping and holding heat in the atmosphere. Huge methane reserves lurk beneath the seafloor, and ocean warming is expected to unlock some of that trapped methane. Understanding how the tides impact these emissions is important for future climate predictions.

To confirm this tidal effect, researchers measured the pressure and temperature inside the sediments, finding out that gas levels near the seafloor rise and fall with the tides. By using a permanent monitoring tool, the researchers were able to identify methane release in an area of the Arctic Ocean where it has not previously been observed.



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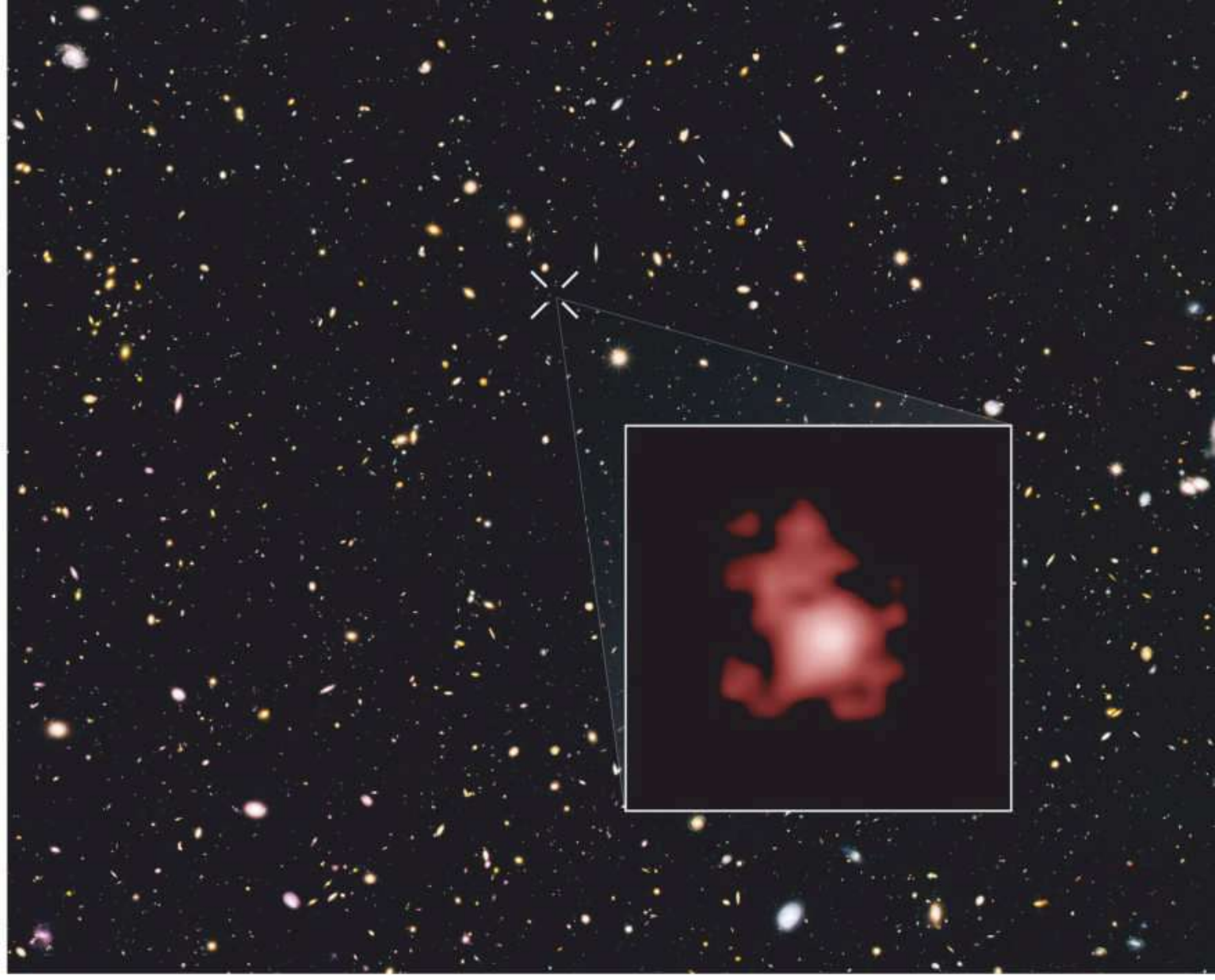
In this digital reconstruction, methane can be seen rising as flares from the seafloor



The galaxy GN-z11, which scientists think could be the farthest and oldest galaxy ever observed, superimposed onto an image from the GOODS-North survey

SPACE & PHYSICS

Scientists spot the farthest galaxy in the universe

Words by **Chelsea Gohd**

Astronomers have peered out into the vast expanse and spotted what they think is the farthest – and oldest – galaxy ever observed. GN-z11 appears to be the most distant and oldest galaxy ever detected. Astronomers led by Nobunari Kashikawa, a professor in the department of astronomy at the University of Tokyo, embarked on a mission to find the universe's most distant observable galaxy to learn more about how it formed.

"From previous studies, the galaxy GN-z11 seems to be the farthest detectable galaxy from us at 13.4 billion light years, or 134 nonillion kilometres [83 nonillion miles]," said Kashikawa. "But measuring and verifying such a distance is not an easy task." To determine how far GN-z11 is from us here on planet Earth, Kashikawa's team studied the galaxy's redshift, how much its light has stretched out, or shifted, towards the red end of the spectrum. In general, the farther away a cosmic object is from Earth, the more redshifted its light will be.

The team also looked at GN-z11's emission lines, observable chemical signatures in the light coming from cosmic objects. By studying these signatures closely, the team was able to figure out how far the light coming from GN-z11 must have travelled to get to us, giving them the tools to estimate its overall distance from Earth. "We looked at ultraviolet light specifically, as that is the area of the electromagnetic spectrum we expected to find the redshifted chemical signatures," Kashikawa said. "The Hubble Space Telescope detected the signature multiple times in the spectrum of GN-z11."

"We looked at ultraviolet light specifically"

"However," he added, "even Hubble cannot resolve ultraviolet emission lines to the degree we needed. So we turned to a more up-to-date ground-based spectrograph, an instrument to measure emission lines, the Multi-Object Spectrometer For Infra-Red Exploration (MOSFIRE), which is mounted to the Keck I telescope in Hawaii." Using MOSFIRE, the team was able to observe and study the emission lines coming from the galaxy in detail. If other observations confirm the new findings, GN-z11 would officially reign as the most distant galaxy ever seen.

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HISTORY

Tudor gold coin stash found in English garden

Words by **Laura Geggel**

A family in England was weeding their garden when they unearthed a valuable treasure, a buried hoard of gold coins dating back to the 1400s depicting English monarchs from Edward IV to Henry VIII. The hoard, a stash of 63 gold coins and one silver coin, contains money minted over a period of nearly 100 years, from the late 15th to the 16th century. Four of the coins feature Henry VIII and, curiously, one of the initials of three of his wives: Catherine of Aragon, Anne Boleyn and Jane Seymour.

Upon finding the cache, the family, in the New Forest of Hampshire in southeastern England, notified the British Museum, which runs the Portable Antiquities Scheme (PAS). This program partners with local people who find historical artefacts in the United Kingdom so that the findings can be documented and studied.

The coins were likely buried in about 1540, while King Henry VIII was still alive, but it's unknown whether this burial spot was like a piggy bank where someone regularly deposited coins, or whether the hoard was buried all at once. Whoever saved the coins, however, was a person of means. The collection was worth about £24 at the time, the equivalent of £14,000 today, Barrie Cook, a curator of medieval and early modern coins at the British Museum, said. That's much more than the average annual wage during Tudor times.

In all likelihood, a wealthy merchant or clergy member buried the hoard, John Naylor, a coin expert from the Ashmolean Museum at the University of Oxford, said. "You have this period in the late 1530s and 1540s where you have the Dissolution of the Monasteries, and we do know that some churches did try to hide their wealth, hoping they would be able to keep it in the long-term," he said.

The newfound coins are "an important hoard," Naylor added. "You don't get these big gold hoards very often from this period." As for the coins themselves, it's a mystery why the initials of Henry's wives were present. In 1526, Henry and Thomas Wolsey, an English archbishop, statesman and cardinal of the Catholic Church, reorganised the monetary system, changing coins' weights and beginning new denominations, such as the five-shilling gold coin.

"Not only does he change denominations, he has this very strange decision of putting his wife's initial on the coin," Cook said. Such a move had no precedent. And given Henry VIII's many marriages – six in all – the initials changed frequently. But after his third marriage to Jane Seymour, the mother of Edward VI who died shortly after giving birth to the future king, Henry discontinued the practice, meaning that his following wives Anne of Cleves, Catherine Howard and Catherine Parr did not see their initials on English money.

The hoard is just one of over 47,000 artefacts documented by PAS in 2020. Another notable newfound hoard includes the 50 South African Krugerrand minted during apartheid in the 1970s.

© The Trustees of the Br t sh Museum

A newfound stash of 63 gold and one silver coin dates from the time of Edward IV to Henry VIII

© Getty

This photo shows the Five-hundred-meter Aperture Spherical Telescope in southwest China

SPACE & PHYSICS

China gives global access to world's largest radio telescope

Words by **Chelsea Gohd**

Following the collapse of the historic Arecibo Observatory telescope in Puerto Rico, China has opened the biggest radio telescope in the world up to international scientists. In Pingtang, Guizhou, stands the Five-hundred-meter Aperture Spherical Telescope (FAST), the largest radio telescope in the world, surpassing the Arecibo Telescope, which stood as the largest in the world for 53 years before the construction of FAST was completed in 2016. Following two cable failures in 2020, the Arebico Telescope collapsed in December 2020, shutting down the telescope for good. Now FAST is opening its doors to astronomers from around the world.

"Our scientific committee aims to make FAST increasingly open to the international community," Wang Qiming, the chief inspector of FAST's operations and development centre said. China will accept requests through 2021 from foreign scientists looking to use the instrument for their research.

With its massive 500-metre diameter dish, FAST is not only larger than the now-destroyed Arecibo telescope, but it's also three-times more sensitive. FAST, which began full operations in January of this year, is also surrounded by a three-mile 'radio silence' zone in which mobile phones and computers are not allowed.

Radio telescopes like FAST use antennae and radio receivers to detect radio waves from radio sources in the cosmos, such as stars, galaxies and black holes. Researchers may use FAST to explore the universe, but may also use the telescope to study alien worlds and to search for alien life.

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WISH LIST

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Making it easy to both wirelessly charge your phone and keep it clean, this device by Belkin is a must-have phone gadget for 2021. Thanks to its built-in dual-sanitising UVC LED lights, it promises approximately 99.99 per cent of bacteria elimination on nonporous items such as smartphones, rings, cash or keys in up to ten minutes. Simply place your Qi charging-enabled smartphone on the top of the device for wireless charging, which can be achieved through phone cases up to three-millimetres thick.

© Belkin

© Duolink

Duolink

Price: **$149 (approx £110)**
www.duolinkgo.com

The Duolink is one of the most diverse smartphone sound system gadgets out there. Depending on your listening needs, this portable speaker can operate in party mode as a single speaker, duo mode for cinematic listening or solo mode as a pair of wireless earbuds. The Duolink is the Swiss Army knife of Bluetooth sound systems and offers intelligent sound cancelling with up to six-hour playback on a single charge and a built-in microphone for voice calls.

Instax mini Link

Price: **£109.99 (approx. $148)**
www.instax.co.uk

Bring your camera roll to life with the Instax mini Link. It's a novelty to print out captured images today, but with this portable printer you can create physical copies of your smartphone's photos with a simple tap of an app. It only takes around 12 seconds for an image to emerge from the printer, and it can print around 100 pictures on a single charge. It's not just your photos that can be printed, but also any frames from recorded footage. The printer can also act as a remote control for your smartphone for a group shot. Simply set up the phone, get into the frame and hit the button on the printer to snap the shot.

© Fujifilm

K480 wireless keyboard

Price: **£54.99 / $49.99**
www.logitech.com

Transform your smartphone into a computer monitor with this portable Bluetooth keyboard from Logitech. This slimline keyboard is capable of housing three devices in its cradle at one time and can switch between them at the turn of a dial – useful if you're working across your smartphone and tablets. Spill-resistant and lightweight, the K480 also promises an impressive battery life of up to 24 months, based on use and computer condition.

Insta360 Nano S

Price: **£249 / $239**
www.insta360.com

This pocket-sized camera records video in 360 degrees up to a 4K resolution. Capturing high-quality images and footage, the Nano S can also be used in real time during video calls. The accompanying app allows you to easily cut and edit any footage and format it for social media posts and online sharing. This accessory also uses your smartphone's built-in gyroscope to counteract shaking hands or wobbly walking for smooth footage.

DJI Osmo Mobile 3

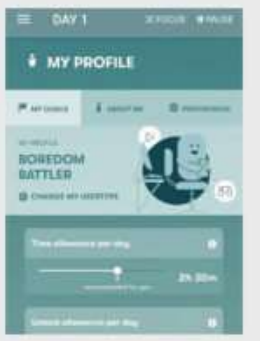
Price: **£99 / $99**
www.dji.com

We all have photos in our camera roll that would have been great had it not been for shaky hands, or video footage that's ruined by unsteady steps. However, with gimbals such as the Osmo Mobile 3, you can film and take stunningly stable images with ease. This three-axis gimbal is ultra-responsive, smooth and lightweight, allowing you to focus on capturing the moment. The Osmo Mobile 3 is foldable and equipped with an ergonomic handle for easy transport and comfortable handling. It's also packed with tracking and zoom features to make sure your subject is always in focus and captured in the best quality.

APPS & TOOLS

SPACE: Break phone addiction, stay focused

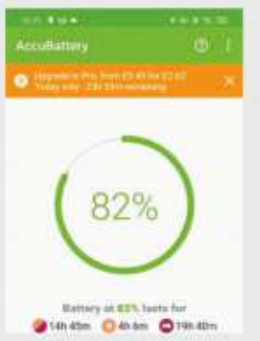
Developer: **Mobifolio**
Price: **Free / Google Play / App Store**



Do you know how much time you spend on your phone every day? Find out with this tracking app that monitors your phone use, duration and habits.

AccuBattery

Developer: **Digibites**
Price: **Free / Google Play**



Keep an eye on your phone's battery health with this tracking app. From power use to charging speed, find out how you're spending energy.

Pacer Pedometer: Walking, Running, Step Challenges

Developer: **Pacer Health**
Price: **Free / Google Play / App Store**

Whether you're looking to improve your fitness or want to know more about how much you move in a day, this easy-to-use app allows you to see your steps.

Sleep Cycle: Sleep analysis & Smart alarm clock

Developer: **Sleep Cycle AB**
Price: **Free / Google Play / App Store**

Not only will this app record your sleep patterns during the night, but will sound the alarm to wake up during a period of light sleep for a natural awakening.

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HOW TO BUILD A WARSHIP
The Royal Navy is updating its fleet, here's how it builds its future-proofed, world-class combat vessels

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HOW TO BUILD A WARSHIP

Words by **Mike Jennings**

The Royal Navy is updating its fleet: here's how it builds its future-proofed, world-class combat vessels

The UK has been known for the strength of its Royal Navy for hundreds of years, and that's unlikely to change any time soon. The organisation has embarked on a program of shipbuilding that's going to modernise its current fleet. It's an expensive, long-term undertaking, but the Navy is certain that its new Type 26 and Type 31 vessels are going to be crucial – and successful – when it comes to maintaining the UK's status as a leading global force. It's not just about keeping the Royal Navy on top when it comes to military hardware, either. The Navy provides humanitarian assistance during natural disasters, protects trade interests and supports the UK's international relationships. It's a broad list of tasks, and new equipment is needed to get these jobs done in the coming decades.

Alongside the carriers in the modern Royal Navy are a range of ships of various sizes, including aircraft carriers and destroyers

DID YOU KNOW? *The smaller Type 31 frigate is constructed from more than 170 units, and each weighs as much as 15 cars*

SHIP

ready to carry out a wide range of duties around the world, wherever the country needs them. Among them are the frigates, the most populous major warship in the fleet, capable of undertaking virtually every kind of mission around the world. They're the Royal Navy's workhorses.

In addition to these core ship classes you'll find several support vehicles – from fuel tankers to patrol boats – and the medical vessel RFA Argus. That doesn't just mean that the Royal Navy needs a large, versatile fleet – it means that the organisation needs to stay on top of the latest technology in order to maintain its position as one of the world's best naval forces.

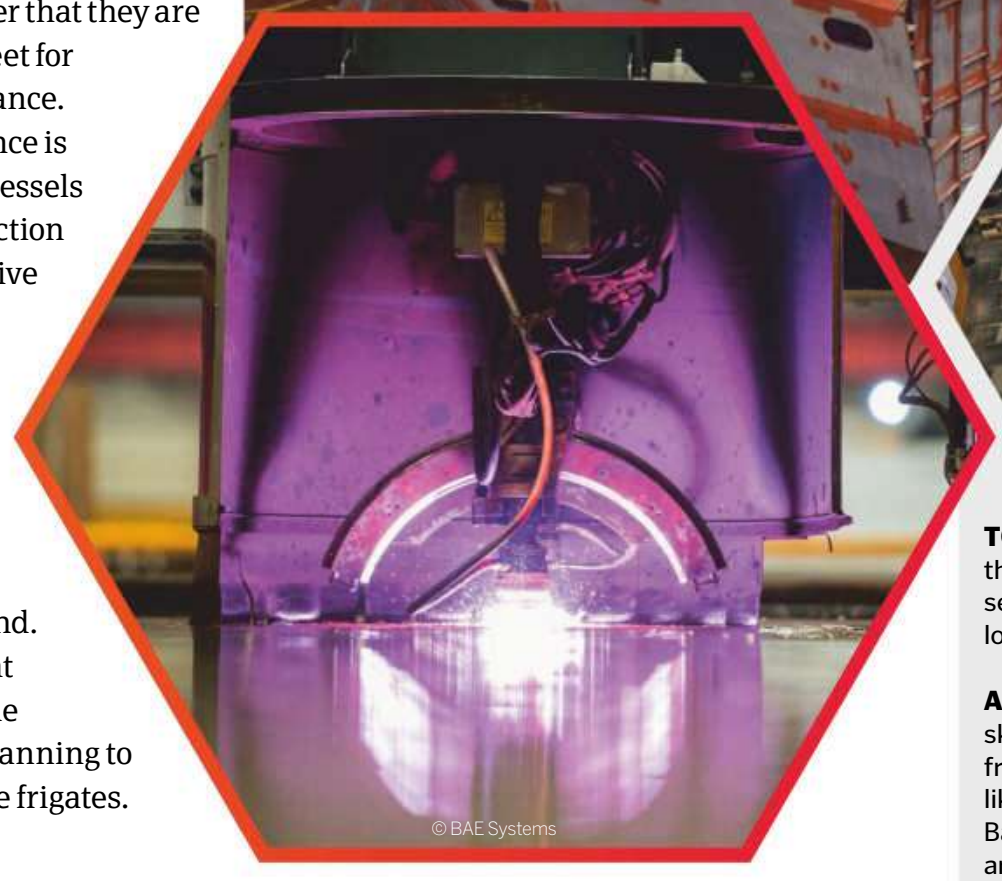
This is where the Type 26 and Type 31 frigates come in. The Royal Navy is currently in the middle of building these incredible new vessels, and they've been designed to replace the existing Type 23 frigate, otherwise known as the Duke class of ships.

Images © MOD

© BAE Systems

These ship upgrades have been planned for a long time. The seeds for the Type 26 were sown way back in 1998, and there were many different designs and plans. But in 2010 things progressed in a big way. The Type 26 emerged from a government defence review and was also described as the Global Combat Ship, with the Ministry of Defence intending to produce ships for the Royal Navy and for export to other countries. It's no wonder that this process takes such a long time when you consider that they are designed to form part of a naval fleet for decades. Nothing can be left to chance.

At present, the Ministry of Defence is planning to deploy eight Type 26 vessels – two are currently under construction and one has been ordered, while five more are planned for the years following. Variants based on the Type 26 design are also being developed for the Royal Australian Navy and the Royal Canadian Navy, and there are partnerships in the works with navies from Brazil and New Zealand. The Type 31 also emerged from that government review in 2010, and the Ministry of Defence is currently planning to order five of these general-purpose frigates.


© BAE Systems

© Getty

TOP: Components like the bridge are built separately and then lowered onto the ship

ABOVE LEFT: Specialist skills are needed to build frigates, so companies like BAE Systems, Babcock and Rolls-Royce are contracted

ABOVE RIGHT: These communications masts were made in Wales

TYPE CASTING

Let's start with the Type 26 – the biggest and more expensive of the two new ships. It's going to tackle a wide range of tasks that face the Royal Navy now and in the future. The new vessel will use a modular design that will enable it to be built to differing configurations and to be more easily fitted with new components in the future.

The Type 26 will have a 3D search radar, 48 launching systems for air-defence missiles, anti-submarine rockets, anti-ship missiles and other weaponry, and it'll have an acoustically dampened hull to make it harder for submarines to spot the ships. There's a dizzying array of technology on board elsewhere, including sonar arrays, naval guns, gas turbines and electric motors, alongside diesel generators and room for high-end Merlin and Wildcat helicopters.

It's a fearsome amount of kit, and these Type 26 ships come with a suitably impressive list of statistics. The Type 26 frigates will be called the

THE TYPE 26'S COMPUTERS CARRY AS MUCH DATA AS 1.5 MILLION TV CHANNELS

SHIP-BUILDING SITES

Most of the Type 26's exterior building work is taking place at BAE Systems' Ship Block and Outfit Hall at Govan in Glasgow, and BAE has invested more than £100 million (about $135 million) in its facilities at Govan and Scotstoun to support the manufacturing program. Unsurprisingly, building ships like this is complicated, which means that several different facilities are being used. The Type 26's individual modules are being constructed at a dedicated fabrication facility at the Govan shipyard, and the fore and aft sections of the ship will be built separately. Once they're done, the two sections will actually leave the huge halls that are usually associated with shipbuilding, and they will be connected and then topped off with the funnels, mast and bridge while the vessel is outdoors. Unusually, that means that two-thirds of the Type 26's construction time will be spent outside.

©Getty

The BAE Systems shipyard in Govan, Glasgow, where the first Type-26is being finished

BUILDING A BATTLESHIP

Building a frigate like the HMS Glasgow is a complex process

1 Piece by piece

The first stage of the building process involves constructing parts of the ship in smaller sections – modules that will house the ship's various rooms, facilities and equipment.

2 Joining forces

Once the modules are built, they're combined into the larger front and rear sections. These will leave the shipbuilding hall in Glasgow and sit in front of the vast building.

3 Building bridges

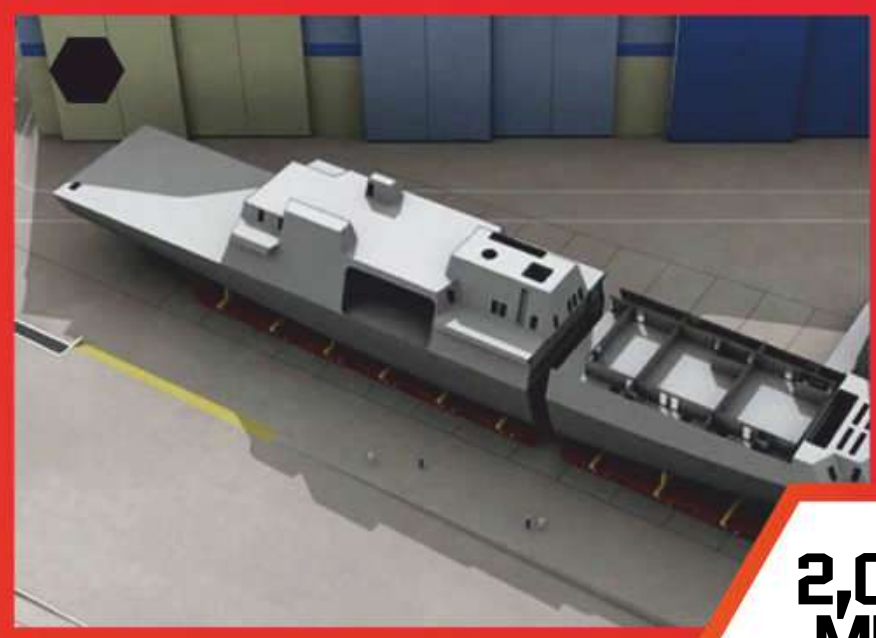
The two halves of the Type 26 will be lined up outside of the shipbuilding hall along with other components like the bridge and mast, which are constructed elsewhere.

4 Topping it off

The fore and aft sections are joined together, and then the components like the mast, bridge and funnels are lifted onto the ship by crane and installed.

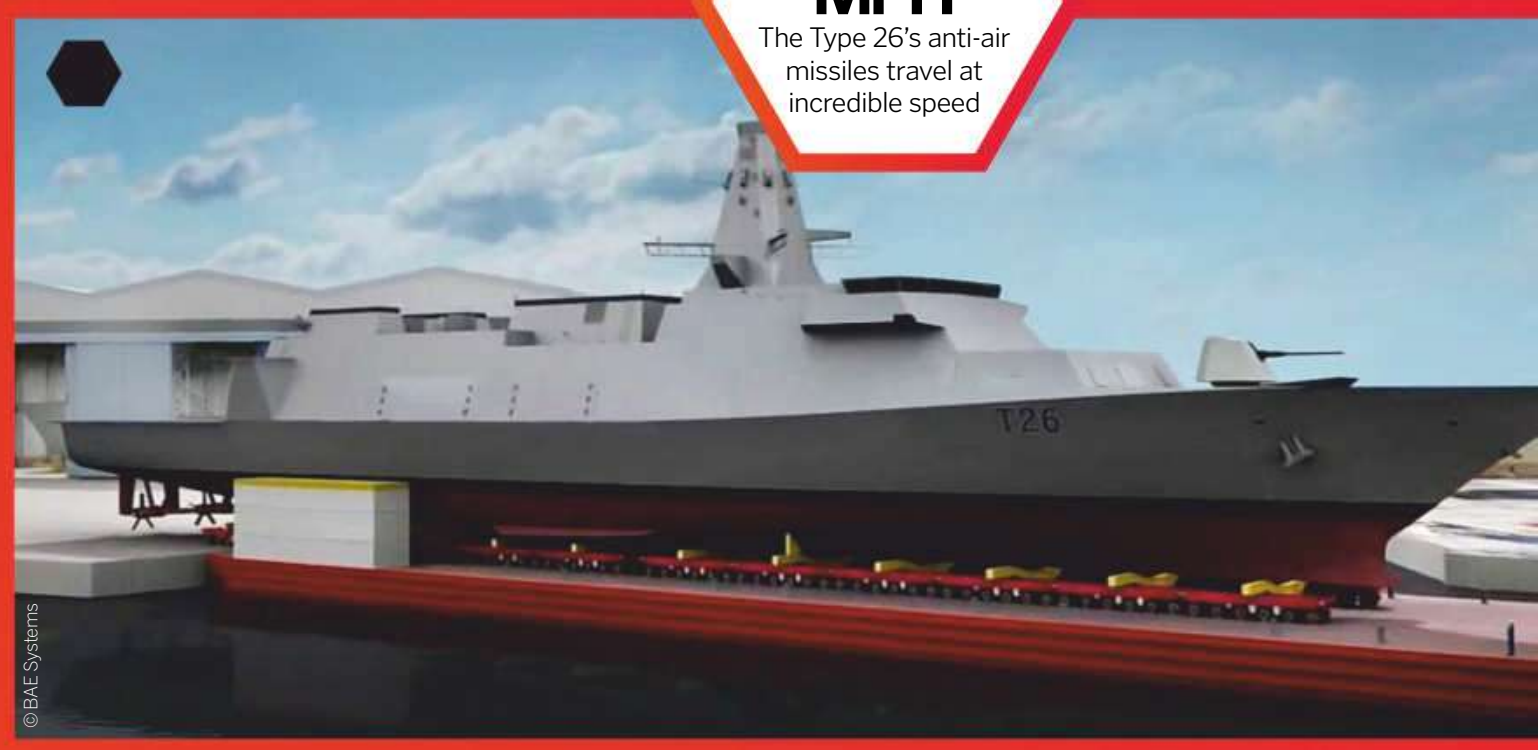
5 Hitting the water

A special barge is used to move the ship from the dockside and into the River Clyde, and it'll be towed to another shipyard for the internal kit to be fitted.



2,000 MPH

The Type 26's anti-air missiles travel at incredible speed



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THE TYPE 31'S INNOVATIVE MANUFACTURING

The Type 31 frigate shares its modular approach with the Type 26. This design strategy is a key part of the UK's approach to shipbuilding, and it allows ship designs to be tweaked and upgraded – and sold to other countries. These smaller ships are being built by Babcock International rather than BAE Systems, and Babcock is spending £50 million (about $70 million) on a new hall to construct these vessels. Individual ship modules will be rolled into this new hall on self-propelled transporters, moved into position using cranes and then attached to other modules. Once the ship's hull is complete, it will be moved outdoors so the mast, bridge and other components can be fitted – just like the Type 26.

The Type 31 is produced in modules, just like the Type 26, for easier building

© MOD

City class. These City-class ships will be 149.9 metres long and have a displacement of 6,900 tonnes – and that will increase to more than 8,000 tonnes once they're fully loaded. Those huge numbers mean that these vessels will be the length of one-and-a-half football pitches and weigh almost as much as the Eiffel Tower. The ships will have a range of 7,000 nautical miles and a standard crew complement of 157 that can be increased to a maximum of 208.

The first Type 26 is called the HMS Glasgow in honour of the city where it's being built. The next two frigates will be called HMS Cardiff and HMS Belfast, and the five that are planned beyond that are also going to be named after other cities in the UK. The innovative modular design is already paying off. Australia's vessels will be called the Hunter class. They're going to be heavier and support a larger crew than the UK's ships, with a different array of guns. The Canadian Surface Combatant ship will be a little longer than the other two, with different sensor systems and weapons and an even larger crew.

"THE NAVY'S NEW FRIGATES ARE IMPRESSIVE, EXPENSIVE AND COMPLEX"

15 miles
The Type 26's pipework would be three-times taller than Mount Everest if stood upright

THE NEW FRIGATES EXPLORED

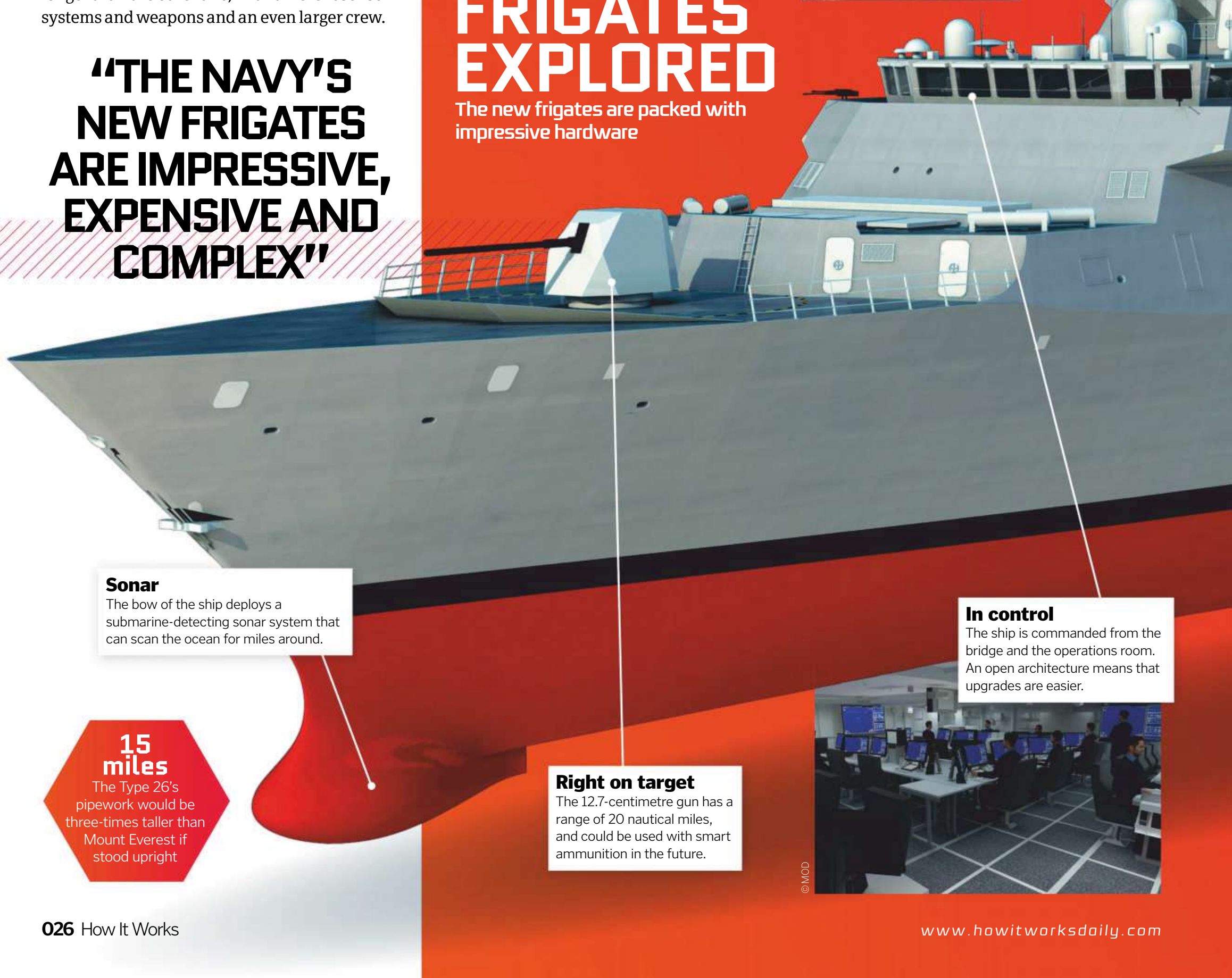
The new frigates are packed with impressive hardware

Mid-range muscle
The Type 31 has a flight deck, just like the Type 26, but this ship only accommodates smaller helicopters.

Shared characteristics
The front of the Type 31 features a bridge, ops room and a gun – just like the Type 26.

Flight hangar
Both new ships have flexible mission bays and secondary flight hangars, but they're smaller on the Type 31.

© MOD



Sonar
The bow of the ship deploys a submarine-detecting sonar system that can scan the ocean for miles around.

Right on target
The 12.7-centimetre gun has a range of 20 nautical miles, and could be used with smart ammunition in the future.

In control
The ship is commanded from the bridge and the operations room. An open architecture means that upgrades are easier.

© MOD

DID YOU KNOW? *The Type 26 frigate has a top speed of more than 26 knots; the Type 31 can reach speeds of over 28 knots*

© MOD

World-leading versatility

All sorts of hardware can be stored in the mission bay, from boats and vehicles to supplies for disaster relief.

High-end weapons

The Type 26 has sophisticated anti-air defence systems, and its radar offers unrivalled protection for detecting threats and jamming cyber attacks.

The 6.5-tonne turbine is paired with electric motors and diesel generators

© Rolls-Royce

QUIET, FAST AND FUNCTIONAL

One of the Type 26's main functions is to combat the threat of submarine attacks, and that means this frigate needs a unique set of technologies. The threat of underwater attack means that the propulsion system has been designed with stealth in mind, so the vessel's Rolls-Royce MT30 gas turbine is combined with electric motors to reduce noise. Elsewhere, the Type 26 has special pipework, shock-resistant mounting and acoustic enclosures to reduce noise. The hull is shaped and lined in order to cut back on noise output, too. All of these features combine to make the Type 26 quieter and stealthier than any Navy ship before it – important when defending on the high seas.

© MOD

Silent sailing

The frigate is powered by a Rolls-Royce gas turbine and diesel generators, and the hull is designed to reduce noise.

© MOD

TYPE 26 FRIGATES WILL BE BASED AT HMNB DEVONPORT, PLYMOUTH, IN SOUTHWEST ENGLAND

Air and sea options

At the rear is a flight deck, which can house a large helicopter for missions away from the ship.

© MOD

The Type 31 frigates are around ten metres shorter than the Type 26 vessels, and they're a little lighter. They'll need a smaller crew of around 100, and they have fewer weapons systems, but they're faster, and have a wider range. Unsurprisingly, these ships aren't cheap. The Royal Navy, the Ministry of Defence and the government spent plenty of time wrangling over designs and costs, but the first order of three Type 26 frigates came in 2017 for £3.7 billion (about $4.9 billion) – so they're working out at more than £1 billion (around $1.35 billion) per ship. The smaller Type 31 ships cost around £250 million (about $340 million) each.

BUILDING BLOCKS

There's no doubt about it, the Type 26 and Type 31 frigates are impressive. But they're also expensive and complex, and the Royal Navy doesn't build them itself. Because of the specialist equipment and skills required, they hire shipbuilding firms to take on the mammoth task. The Type 26 frigates are being built by BAE Systems, and more than 40 other suppliers are producing components, including Rolls-Royce – the entire process supports more than 3,000 jobs.

The first of the UK's Type 26 ships is under construction at BAE's Ship Block and Outfit Hall in Glasgow. The modular design means that the ship is being built in huge blocks which go together to form the front and rear halves of the ship – in nautical terms, they're the 'fore' and 'aft' sections. Those sections are pieced together, all of the piping and cabling is linked up and then the hull of the HMS Glasgow will be structurally complete. Once that's done, the funnels, mast and bridge will be lifted onto the hull by cranes and attached securely. During 2021 the entire vessel will be rolled onto a huge barge that will be used to lower the ship into the water of the River Clyde.

© BAE Systems

THE SHIP'S CREW QUARTERS INCLUDE RECREATION AREAS AND A GYM

© Rolls-Royce

ABOVE: The front and rear sections of the ship are built separately, then connected outside

RIGHT: The frigate's mission bay can hold boats, supplies or other vehicles – whatever is necessary

Once the ship is lowered into the river, it's going to be towed down the River Clyde to another BAE shipyard at Scotstoun. It's here where the vessel will be 'fitted out', meaning that the rest of the construction will be finished. This part of the process mostly involves kitting out the interior of the ship. It's planned that the first Type 26 frigate will be accepted by the Royal Navy in 2025, becoming operational by 2027. The first Type 31 ships are also planned to be operational by 2027.

"THE FIRST TYPE 26 IS CALLED THE HMS GLASGOW"

ROYAL NAVY SHIPS THROUGH THE AGES

1511

© Alamy

MARY ROSE

RN ship type: Carrack

The Mary Rose was King Henry VIII's flagship. It served for 33 years, but sank near the Isle of Wight.

1637

SOVEREIGN OF THE SEAS

RN ship type: Ship of the line

This fearsome flagship – nicknamed 'Golden Devil' – was the first vessel with three gun decks, since King Charles I demanded more firepower.

1765

© Getty

HMS VICTORY

RN ship type: Ship of the line

The Royal Navy's most famous vessel was Nelson's flagship at the Battle of Trafalgar, and is today docked in Portsmouth.

1820

© Alamy

HMS BEAGLE

RN ship type: Brig-sloop

This survey ship was famed for carrying naturalist Charles Darwin on his influential voyages around the world.

1891

HMS ROYAL SOVEREIGN

RN ship type: Battleship

This 14,150-tonne vessel was the largest warship in the world when built. It was eventually sold for scrap.

1906

HMS DREADNOUGHT

RN ship type: Battleship

This was the fastest and best-armed battleship in the world at the time. It made other ships immediately obsolete because of its firepower.

Q&A DIRECTOR FOR TYPE-26 FRIGATES

Rear Admiral Paul Marshall CBE, the senior officer responsible for delivering these latest warships, explains their role in the Royal Navy

© Ministry of Defence

Rear Admiral Marshall has embarked on naval tours to Asia, the Caribbean and Africa

How will the Type 26 and Type 31 frigates fit into the current Royal Navy fleet?

The larger Type 26 is an advanced anti-submarine warfare warship designed to support the UK's other vessels. As well as protecting us from submarines, the Type 26 will support operations across our full spectrum of tasks, including counter-piracy missions, disaster relief work and delivering humanitarian aid. It's going to be around for a long time – the Type 26 is designed for a service life of 25 years, so it'll be an essential component of the Royal Navy fleet into the 2060s.

The Type 31 will also be at the heart of our fleet – deterring aggression, maintaining the UK's interests and helping those in need. The Type 31 is designed to relieve the operational pressures on other ships, including the Type 26, so those vessels are freed up to tackle specialist tasks. That means the Type 31 doesn't have the anti-submarine features that are included on the Type 26.

What weapons will the Type 26 be equipped with when it launches, and what will be added in the future?

The Type 26 has a flexible design that will enable its capabilities to be adapted throughout its life span in order to counter future threats. The HMS Glasgow will enter service with a Sea Ceptor air defence missile system and a 12.7-centimetre medium-calibre gun. The Type 26 can also embark with a Merlin anti-submarine helicopter or a Wildcat maritime attack helicopter. The Wildcat will be able to deploy two variants of our Future Anti-Surface Guided Weapon.

The Type 26 frigate will be fitted with the Mark 41 Vertical Launching System, which provides the flexibility to field a variety of weapons, and that may include our next generation of ship-launched strike weapons. The Type 26 is inherently flexible, which allows us greater choice when planning operations and upgrades. That's important because it allows us to upgrade the ship's systems throughout its lifetime so it can tackle future threats.

What sort of facilities will be included for the crew on the HMS Glasgow?

As with all warships in the Royal Navy, the Type 26 will be fitted with a sickbay and ward. A number of our personnel are trained in first aid, and depending on the mission we'll have specialist medical personnel on board. When operating as part of a larger strike group, personnel will have access to a wider range of equipment and staff.

In addition, the Type 26 will be fitted with a gym that includes weightlifting and cardio equipment, and a physical trainer will be part of the ship's crew so they can provide the crew with specific training programs and guidance on healthy eating.

The crew's accommodations have recreation areas with TVs and games consoles, and social areas for people to congregate. There will be a library, and personnel can also access a range of TV and radio stations through the British Forces Broadcasting Service.

1913 – HMS WARSPITE

RN ship type: Battleship

A vessel that served in both World Wars, thanks to extensive modernisation and a stellar design. It was a Queen Elizabeth-class ship, reaching speeds of 23 knots.

1916 – HMS FURIOUS

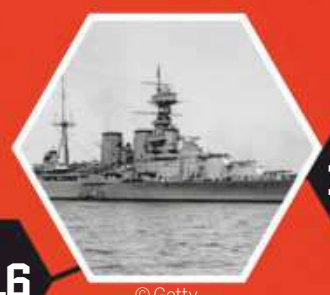
RN ship type: Battlecruiser

The Royal Navy's first aircraft carrier happened due to design changes – it was originally designed as a conventional cruiser before its forward turret was replaced with a flight deck.

1918 – HMS HOOD

RN ship type: Battlecruiser

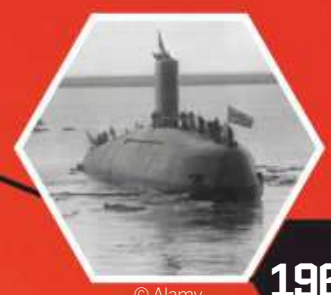
This famous but flawed ship was infamously sunk by the German battleship Bismarck in 1941.


© Getty

1960 – HMS DREADNOUGHT

RN ship type: Submarine

The second HMS Dreadnought was the UK's first nuclear submarine, and was launched on Trafalgar Day.


© Alamy

1977 – HMS INVINCIBLE

RN ship type: Aircraft carrier

This aircraft carrier was the flagship of the Royal Navy's fleet and saw action in several wars.

© Alamy

2017 – HMS QUEEN ELIZABETH

RN ship type: Aircraft carrier

This new flagship aircraft carrier is the Royal Navy's largest-ever warship and can carry more than 60 aircraft.

© Alamy

LANDING A PLANE

Find out how pilots get tonnes of metal down safely to the tarmac

Landing a plane is the most delicate part of a flight. It involves turning a flying craft into a ground vehicle, bringing hundreds of tonnes of mass to the ground without incident while shedding speed along the way. Aircraft will naturally fly: so long as they have sufficient fuel, their aerodynamics are designed to keep them moving. To change this, pilots not only have to reduce engine power, they also must slowly adopt a 'dirty configuration', using aerodynamic drag to reduce speed.

The landing procedure begins miles away from the airport. During this time, many changes in altitude, speed, direction and overall aircraft set-up must be completed. This is mainly conducted in dedicated 'step down airspace', defined by air-traffic control. Passengers are told the landing procedure is due to commence, and are instructed to return to their seats and fasten their seat belts. This is a legal requirement.

At night the cabin lights are dimmed before the landing procedure commences, and window blinds are raised. This is so that in an incident, passengers will be less disorientated. Dimming the lights reduces glare and means eyes will already be adjusted to dim conditions. It will also let some light into the cabin and allow passengers to spot dangers.

Landing is a two-stage process: the approach to landing and landing itself – which will only be successful if the approach is good. During the approach phase, pilots slow the plane from cruising speed to an approach speed, from which they can descend gently to a landing speed. Pilots allow the plane to contact the ground with the lowest possible vertical and horizontal speed.

As throttling back is insufficient to fully slow an aircraft, the additional configuration changes are filtered in at defined approach points. These include gradually raising flaps, and later on in the procedure extending the landing gear. Indeed, such is the drag created in doing this, some engine power must actually be reapplied to compensate.

The pilot's main goal during descent is to reach the runway at a precise point, and they are able to quickly form a mental picture of the destination landing strip as all runways are given a number from 01 to 36. This is their heading, where 36 equals 360 degrees, or due

Visual guide to a cockpit
Backup background
Backup dials are positioned less prominently, but offer an additional readout in case of main dial failure.
Engine indication
Engines are monitored in great depth, with fuel flow and temperature, electrical functions and other parameters analysed.
Glass
Modern jets use glass cockpits. Instead of hundreds of individual instruments, readouts are shown on VDU computer screens.
Basic six
The six instruments to keep an aircraft in flight are airspeed, artificial horizon, a vertical speed indicator, altimeter, directional gyroscope and turn altitude.
Flight management systems
Flight management systems are cutting-edge flight technology. Pilots enter the flight plan through them so they can control speed, navigation and so on.
Mode control panel
A mode control panel allows the pilot to mastermind heading, speed, altitude, vertical speed plus vertical and lateral navigation.

The air-control tower can help guide a plane down onto the runway

north. It enables pilots to quickly visualise the landing direction, and judge how wind conditions may affect this. Runways can have two numbers, for example 34 and 16. They are separated by 18 because it is the same runway operating in two directions.

The final approach procedure is initiated in a 30 to 50 mile radius. Air-traffic control (ATC) staff on the ground receive 'their' approach aircraft from fellow controllers on route. The controller's job is to find a space for the approach aircraft with a safe separation from others entering the centre airspace; they all blend together, with the required separation, into a separate channel for final approach to the runway.

Final approach requires stated clearance from ATC. Sometimes a landing must be aborted at the last moment, either because of an emergency alert from air-traffic control or an override by the pilot. This is called a 'go around' – the aircraft will pitch up sharply, full power will be applied, landing gear and flaps will be tucked away and a very steep climb will be felt.

This can be alarming for passengers, but is actually a specific procedure pilots are trained for. It usually occurs either because a plane is still occupying the runway, or the pilots do not have sufficient visual references to land safely. Passengers will be familiar with delays from being kept in a holding pattern. This is for their own safety and ensures the pilot has the time and space to complete their landing procedures, avoiding 'go around' emergency calls in the process. Holding patterns are predefined and dictated by ATCs in the control tower.

When it's busy, ATC will sometimes specify a defined airspeed for pilots to maintain, usually within an accuracy of ten knots. This is to keep the aircraft in sequence with those in front and behind – it is how the rate of approach to crowded airports is controlled.

ATC allows two forms of instructions to pilots, which will be stated before the procedure commences. The descent itself can be under specific altitude instructions which pilots must obey – this is to further help in traffic separation. Alternatively, the aircraft is cleared to descend at

"The pilot's main goal is to reach the runway at a precise point"

the pilot's discretion. This means the pilots themselves decide speed and rate of descent – the only proviso is that once they leave an altitude, they cannot return to it.

On the technical side, landing procedures are managed by an instrument landing system (ILS). This uses radio beacons situated on the ground to precisely guide a plane down with immense accuracy. An ILS follows a specific glide path that helps the plane follow an 'ideal' three-degree angle to the runway.

ILS radar is often supported by an approach lighting system (ALS) – lightbars, strobes and so on, which are situated at the start of the runway. They are a big aid to pilots, helping them switch from instrument flight to visual flight – and they can also extend the operating range of the airport because they count as part of a 'visual approach'. Pilots must be able to see three-quarters of a mile to the runway: with high-intensity ALS, this can be reduced to half a mile or more if lights extend to parts of the runway.

The final seconds before touchdown are when many passengers hold their breath. Just before

an aircraft touches the ground, the nose will be raised up. This is called a 'flare', and means the main landing wheels touch the ground first. The perfect landing will see the wheels touch the ground just as lift on the wings completely falls away and the plane 'stalls'. To feel hundreds of tonnes of mass controlled in such a precise way is extremely satisfying.

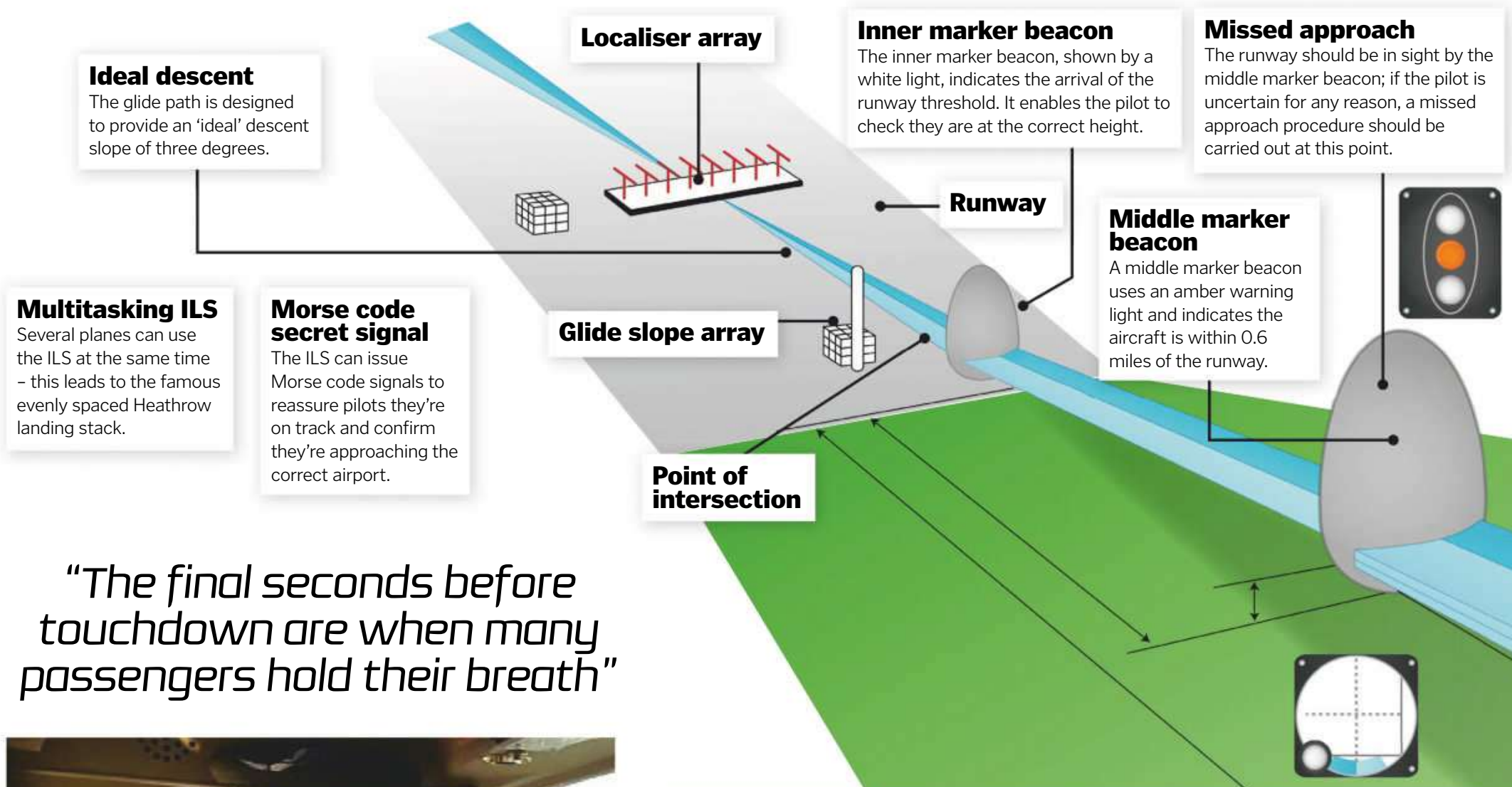
When the rear wheels are on the ground, the pilot does not lower the nose – it drops of its own accord. It does so because as the aircraft loses speed, the flight controls continue to lose effectiveness so gravity can take over. Once all wheels are on the ground, the aircraft is in rollout mode.

Here the flying machine is turned into a ground machine – and must be stopped before the end of the runway. On large jets, the first method of doing this is to raise more flaps to increase drag while engaging reverse thrust on the jet engines. As forces build, pressure on the landing gear increases.

Monitoring each flight's progress is essential for avoiding any midair collisions

Once there's enough mass pressing down on the wheels, the pilot can apply the brakes. Passengers feel this two-stage deceleration in landing – first the engines will roar, and then there will be a slight jolt as the brakes come on. The length of this rollout process depends on the weight of the plane, the runway's gradient, condition and elevation, ambient temperature, brake effectiveness and pilot technique.

Autopilot can actually perform the complete procedure right up to touchdown and rollout. What autopilot cannot do is control the ground taxi process; this will always be done by the pilot, using guidance from ground control. On the ground the aircraft will taxi to its final position, where passengers can disembark.


Ideal descent
The glide path is designed to provide an 'ideal' descent slope of three degrees.
Localiser array
Inner marker beacon
The inner marker beacon, shown by a white light, indicates the arrival of the runway threshold. It enables the pilot to check they are at the correct height.
Missed approach
The runway should be in sight by the middle marker beacon; if the pilot is uncertain for any reason, a missed approach procedure should be carried out at this point.
Runway
Middle marker beacon
A middle marker beacon uses an amber warning light and indicates the aircraft is within 0.6 miles of the runway.
Multitasking ILS
Several planes can use the ILS at the same time – this leads to the famous evenly spaced Heathrow landing stack.
Morse code secret signal
The ILS can issue Morse code signals to reassure pilots they're on track and confirm they're approaching the correct airport.
Glide slope array
Point of intersection

"The final seconds before touchdown are when many passengers hold their breath"

Pilots train for years before they can fly commercially

Instrument landing system explained

An ILS is installed at most important airports, helping land planes accurately, safely and efficiently

Based on the ground, the instrument landing system (ILS) is a standardised system that communicates with the aircraft and guides it to the ground using radio signals. It uses two components to determine a plane's path: a localiser, which controls lateral guidance, and a glide path for vertical guidance.

Localiser antennae emit dual signals of different frequencies either side of the runway. A receiver on the aircraft measures any difference between them and adjusts the approach accordingly. The glide path antennae, situated to one side of the runway, does a similar job for the vertical route.

Approach and landing

A step-by-step guide to how you end up safe and sound on the runway

1 Miles of landing
The landing process may already be underway by the time you buckle your seat belt.

1 Holding stack

2 Air-traffic control
The aircraft will be directed to an ILS localiser via defined headings.

5 Control tower
The aircraft will be supported by air-traffic control based at the tower.

Radio beacon

Terminal building

Control tower

Apron

Secondary radar

Runway

10 Terminal and exit
The aircraft will be directed to the parking apron. Passengers will disembark and head to the terminal.

Glide path

0.6 miles

Eight miles

Middle marker

Primary radar

3 Holding stack spacing
All aircraft landing at an airport will have already been widely spaced many miles before descent.

9 Rollout
The pilot will use aerodynamic devices to create drag and slow the plane, then apply the brakes.

Outer marker

7 Glide path
Aircraft descend at a glide path gradient of around three degrees – ILS is calibrated to ensure this.

4 Marker post guidance
Pilots know how far from the runway they are thanks to marker posts.

6 Pilot remains in control
Air-traffic control manages plane positioning, but pilots always make the final decision in an emergency.

8 The perfect touchdown
The wheels of an aircraft should ideally touch the ground just as lift on the wings reduces to a stall.

Outer marker beacon
The outer marker sounds an alert at up to 8 miles away from the runway, and flashes a purple or blue light on the instrument display.

Directional system
An ILS is directional, so is located on either end of a runway. Additional marker beacons are sometimes included, providing further information to approaching planes.

ILS establishment
Aircraft need to come within 2.5 degrees of the localiser course in order to become established on a final approach route.

Localiser modulation frequency

ATC lead
Air-traffic control directs aircraft to the localiser using defined headings – this keeps good and even spacing between planes.

Glide slope modulation frequency

Landing a plane in an emergency

Let's hope you never have to use this...

No time to make notes

Pilot passed out? No worries, help is at hand. Just follow these simple steps and a successful emergency landing can be achieved. First, sit in the pilot's seat; this is the one positioned on the left of the cabin. Before touching anything, check the altitude instrumentation in front of you. The altitude indicator, often referred to as the virtual horizon, is the circular display that shows a W-shaped representation of the plane's wings in relation to the ground and sky.

Next check whether the autopilot is engaged. If it is and the plane is level, don't touch anything. If the wings are not level, adjust any bank or pitch using the yoke – or stick.

Now phone in the emergency on the radio. Air-traffic control will guide you to a runway, but you'll have to make the landing yourself. Pull back on the throttle – the handled lever on the pilot's right side – to reduce power and push down on the yoke to drop the nose. Drop the landing gear, and just as you are about to touch down, raise the nose so the main wheels touch down first.

Finally, when on the tarmac, engage the reverse thrusters, the movable bars behind the throttle, pull the throttle down to its 'idle' position and apply pressure to the top of the rudder pedals down by your feet to brake.

A jack of all trades, the Humvee can be configured to perform many roles

© AM Genera

A snorkel and raised exhaust make the Humvee a great amphibious vehicle

© AM General

The Humvee

The High Mobility Multipurpose Wheeled Vehicle (HMMWV) roars off the production line ready for action

Designed to replace several outdated American military vehicles, the High Mobility Multipurpose Wheeled Vehicle, or Humvee, has been in production since 1984. Originally intended as a light utility vehicle, there have been more than 20 variants of this highly customisable modular platform. Serving over 40 nations, around 300,000 Humvees have been built to date. Able to carry and deploy almost anything, from fully armed troops to anti-aircraft missiles, the Humvee is an open-topped scout vehicle, an armoured personnel carrier, an ambulance, a TOW missile launcher, a communication centre, a heavy machine gun platform and whatever else the situation requires.

The latest models are unrivalled in their off-road capabilities, and are based around a 6.5-litre V8 Turbo diesel engine which produces 142 kilowatts, or 190 brake horsepower, and 515 Newtons per metre of torque. This power is sent to all four wheels through an electronically controlled four-speed automatic gearbox using a series of differentials.

The drivetrain is rather unconventional as the wheels themselves contain portal-geared hubs; these not only double the torque generated, but due to the offset driveshaft inputs enable the vehicle's ground clearance to be significantly higher than a regular centre axle would allow. This innovative drivetrain, coupled with independent suspension and 94-centimetre tyres, allow the Humvee to travel at up to 70 miles per hour or to climb slopes of 60 per cent – though some Humvees have been seen to climb near-vertical walls.

The internal environment is fully air conditioned, while a deep-water fording kit allows the vehicle to cross rivers almost completely submerged. These capabilities, combined with design features such as the sturdy chassis, corrosion resistance plus high commonality and interchangeable parts, enable the Humvee to be capable, flexible, dependable and rugged even in the harshest of environments.

The turret can be fitted with weapons for all kinds of combat situations

© AM General

Armour options

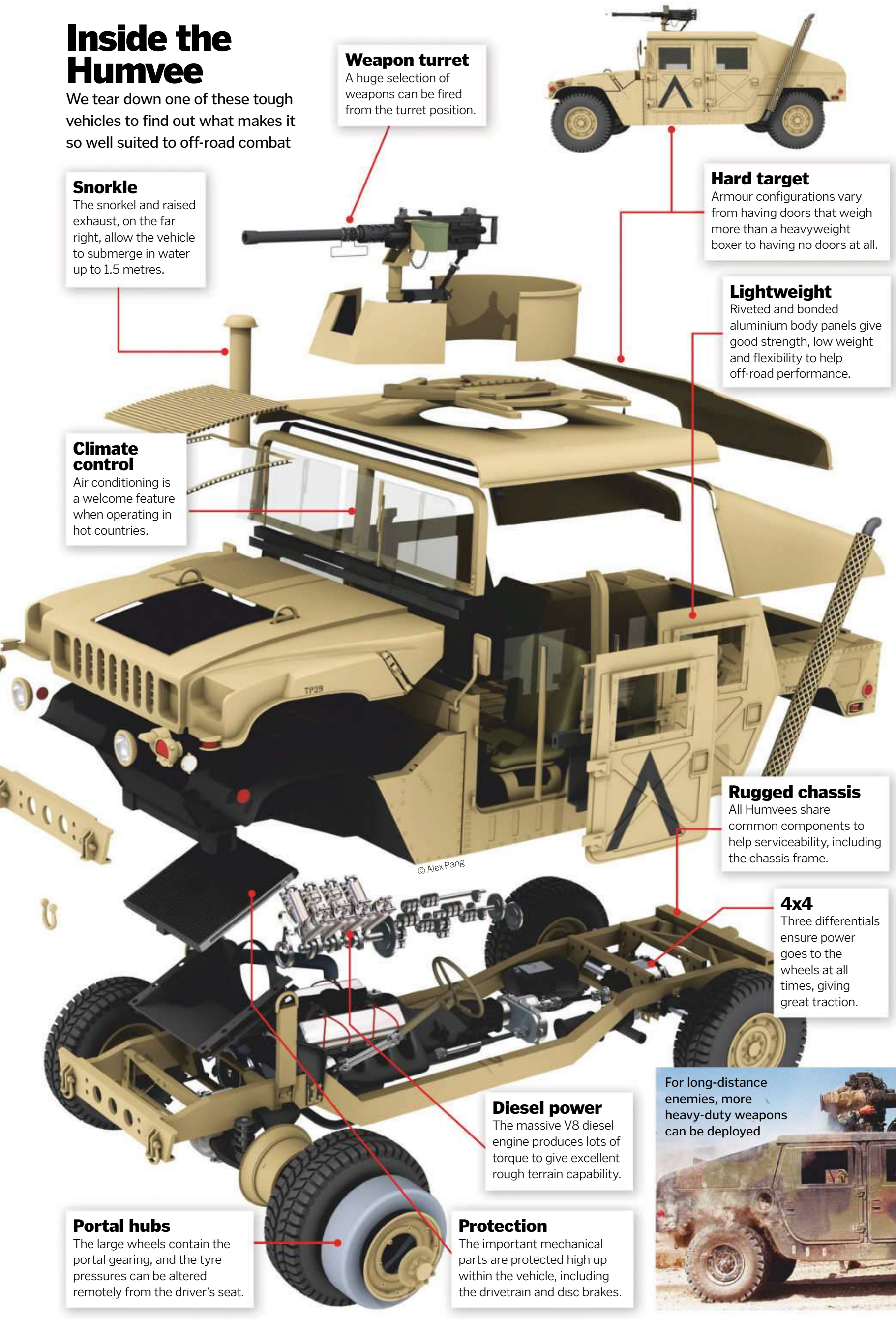
Since the Humvee was introduced, soldiers have demanded increasingly more protection from it. Early versions had fabric doors and no roof, but the demands of combat in Somalia, Iraq and Afghanistan demonstrated the need for improved armour for the vehicle.

Many improvised solutions have been tried in the field in recent years, including sandbags and welding scrap metal to the chassis. However, heavily armoured versions are now available from the factory – as are retrofit kits – which include under-body plates, heavy doors, armoured seats, weapon shields and many other additions.

The latest iterations offer the crew protection from assault rifle bullets, some air-burst artillery and up to 5.4 kilograms of explosives thanks to thick steel armour, energy-absorbing coatings and mounting and reinforced glass. All of this protection comes at a price though. Many Humvees carry 907 to 1,814 kilograms of armour, which can only be taken in place of cargo and equipment. Work is underway to make the Humvee more resistant to buried explosives, as the large, flat floor is not effective against these dangers.

Inside the Humvee

We tear down one of these tough vehicles to find out what makes it so well suited to off-road combat



Weapon turret
A huge selection of weapons can be fired from the turret position.

Snorkle
The snorkel and raised exhaust, on the far right, allow the vehicle to submerge in water up to 1.5 metres.

Climate control
Air conditioning is a welcome feature when operating in hot countries.

Hard target
Armour configurations vary from having doors that weigh more than a heavyweight boxer to having no doors at all.

Lightweight
Riveted and bonded aluminium body panels give good strength, low weight and flexibility to help off-road performance.

Rugged chassis
All Humvees share common components to help serviceability, including the chassis frame.

4x4
Three differentials ensure power goes to the wheels at all times, giving great traction.

Diesel power
The massive V8 diesel engine produces lots of torque to give excellent rough terrain capability.

Portal hubs
The large wheels contain the portal gearing, and the tyre pressures can be altered remotely from the driver's seat.

Protection
The important mechanical parts are protected high up within the vehicle, including the drivetrain and disc brakes.

© Alex Pang

Packing a punch

There was always a need to arm the Humvee to provide fire support and defence, but the variety of weapons it can carry is astonishing.

Starting with a choice of general-purpose machine guns, most weapons can be fired manually or fitted to the remotely operated CROWS turret system. The most common weapon choice is the legendary M2 Browning .50 calibre. However, should there be a need to raze everything in sight to the ground, the gunner can unleash 100 shots per second using the destructive M134 Minigun.

For even more of a brutal bang, the 40-millimetre grenade machine gun can launch 60 high-explosive grenades per minute. Should an enemy bring a tank to the fight, the Humvee can launch the TOW anti-armour missile from 2.3 miles away. In situations requiring a little bit of overkill, the Humvee is also designed to tow a Howitzer cannon.

The ultimately devastating version, however, has to be the Boeing-developed Avenger, which carries up to eight Stinger anti-aircraft missiles, with proposals for additional weapons including a one-kilowatt laser.

For long-distance enemies, more heavy-duty weapons can be deployed

AR ZONE!

Atomic icebreaker

Meet the latest nuclear-powered vessel to sail the frozen seas

The nuclear icebreaker Arktika was moored at the Baltic Shipyard before setting sail for trials in the Arctic Ocean in September 2020

© Getty

Breaking through the Arctic ice of the Northern Sea Route is of paramount importance for Russia. As a vital trading route for the nation, over the years Russia has constructed some of the world's largest and most powerful ships that carve through the ice to maintain a path for passing freight vessels.

Within the last decade, that power has come from the nuclear engines of Russia's Project 22220 vessels. The first vessel and leader of the icebreaker fleet is the Arktika, which began being built at Saint Petersburg-based Baltic Shipyard back in 2012. However, it wasn't until September 2020 that Arktika had its maiden voyage through Arctic waters to the Russian city of Murmansk.

Arktika is known as an LK-60Ya vessel, which refers to the 60 megawatts of power it can produce, thanks to its twin nuclear reactor engines. It's reported that one full load of its nuclear reactor is equivalent to 540,000 tonnes of Arctic diesel fuel, and reloading its nuclear fuel is only required once every seven years.

Nuclear propulsion on the Arktika and many other vessels around the world works like a nuclear power plant – but on a much smaller scale. Within the engine's reactor, a radioactive source such as uranium is triggered into nuclear fission. The useful energy is emitted as heat through an induced chain reaction. The heat turns water into steam, and the steam turns a turbine to generate electricity and power the ship. The more power these engines can produce, the easier it is for icebreakers to power forward and force ice to crack apart.

Arktika is the first icebreaker in a fleet of five more nuclear vessels either under construction or planned for completion by 2035, according to an executive order signed by Russian President Vladimir Putin.

Reactors are continually monitored in the control room

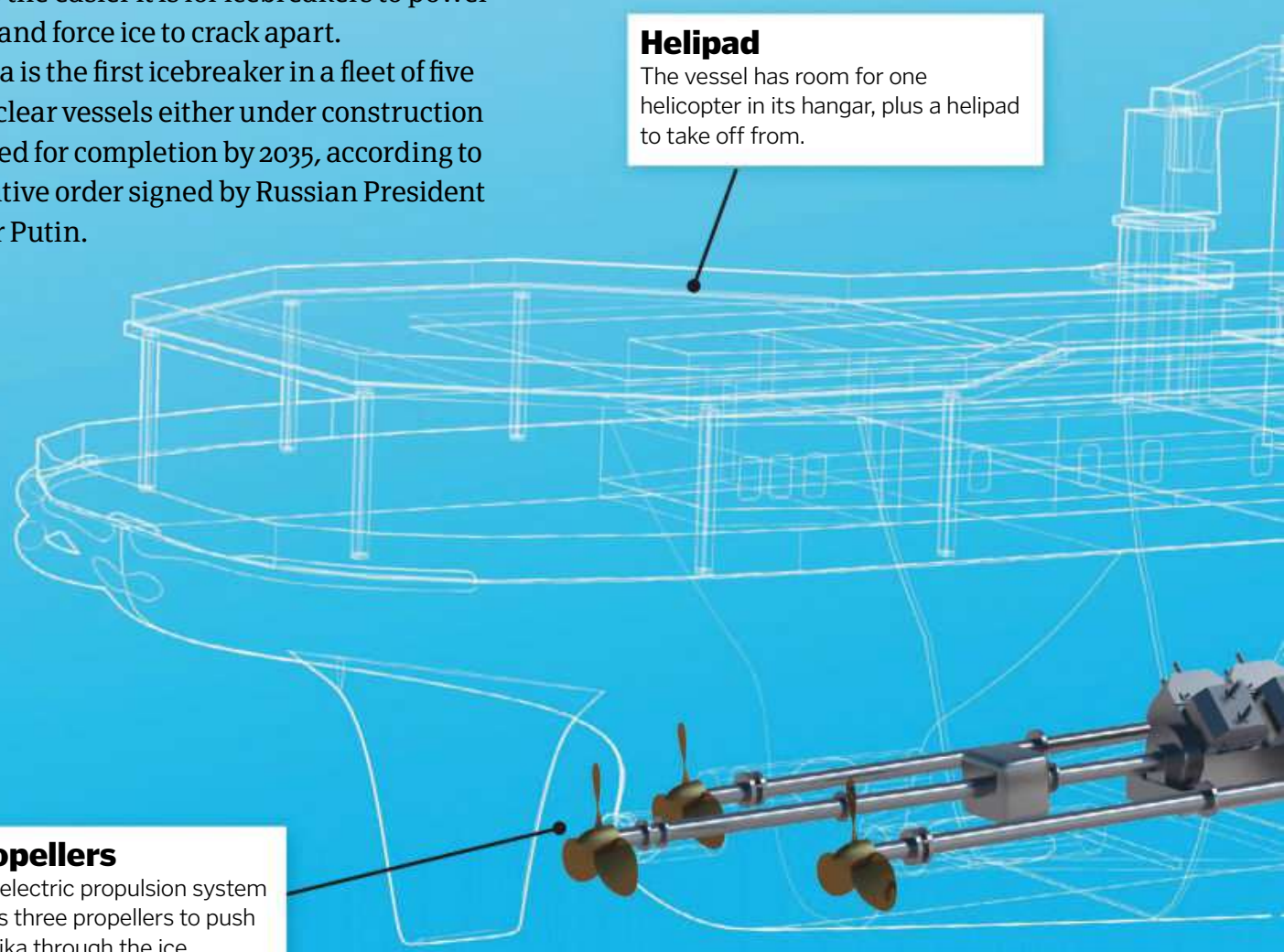
© Getty

Inside Arktika's nuclear reactor compartment, which houses the ship's two RITM-200 reactors

© Getty

Breaking the ice

How the Arktika vessel generates enough power to carve through frozen waters



Helipad
The vessel has room for one helicopter in its hangar, plus a helipad to take off from.

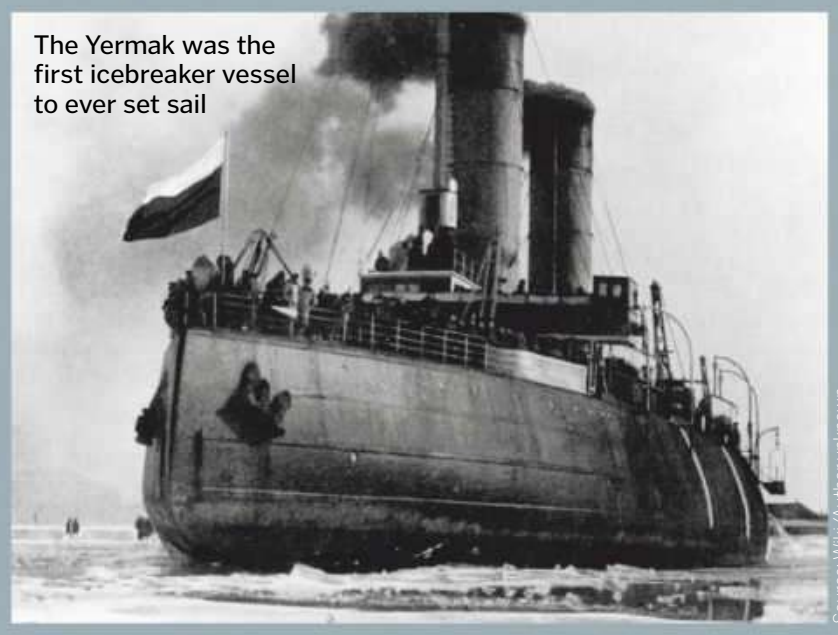
Propellers
The electric propulsion system turns three propellers to push Arktika through the ice.

AR ZONE! SCAN HERE

www.howitworksdaily.com

The first icebreaker

The Yermak was the first ship strong enough to break its way through the ice around the North Pole. After a proposal by Admiral Stepan Osipovich Makarov in 1897, Yermak set sail only two years later. The hull of the ship was 93 metres in length, 21.6 metres wide and was said to be able to break through ice two metres thick. The Yermak facilitated countless expeditions to the Arctic, leaving merchant passageways in its wake. It's reported that in its first 12 years the icebreaker spent over 1,000 days in the ice. During World War I, Yermak was drafted to serve as a rescue vessel for ice-trapped Russian ships.



The Yermak was the first icebreaker vessel to ever set sail

Source: Wiki/Author unknown

Coolant
A chemical coolant is used to condense the steam that's passed through the turbines and recirculate it.

Steam generator
The heat produced by the nuclear reactor core heats the adjacent water and produces steam to turn the turbines.

Reactor core
Uranium-235 is at the core of the nuclear reactor. The natural process of nuclear fission generates the energy needed to heat the adjacent water.

Cockpit
Navigation and communication take place here, where the captain and his officers pilot the vessel.

Power
There are two RITM-200 integral pressurised water reactors, each with a thermal capacity of 175 megawatts.

Turbines
The two reactors produce steam that delivers 60 megawatts to the electric motor propulsion.

Bow breaker
The reinforced hull is shaped so that the front of the ship rides up onto the ice sheet, allowing the weight to crack it apart and create a channel.

33,530 tonnes of displacement

In clear water it can achieve speeds of 22 knots

53 crew capacity

It can break through ice almost three metres deep

34 metres wide

173.3 metres in length

Illustration by © Adrian Mann

BUSH MEDICINE

Aboriginal Australians are experts of the outback, utilising life-saving remedies found in nature

Words by **Ailsa Harvey**

Rural Australia is a harsh environment. The land is dusty and dry, dangers can be hidden and the heat unceasing. You could be tricked into thinking the land is barren. But this is far from the truth. Through a process of trial and error that has taken place over the 60,000-year history of human settlement in Australia, people have thrived on this continent.

Aboriginal Australians share a deep connection to the land, with its physical and spiritual importance taught to them by their ancestors. Their long-told stories say that if you are kind to the environment, it will reciprocate and provide you with everything needed for a fulfilling life. This respect has proved successful, with a huge variety of plants and animals whose chemical make-up holds health benefits in unlikely places.

Understanding the medicinal properties of the country's landscape wasn't a process that occurred overnight. With deserts abundant in venomous animals and toxic plants disguised as tasty treats, unlocking the land's potential came with skill, patience and creativity. For example, when ingesting a poisonous plant like the cycad, family members became sick or died, which was a warning that was passed down generations, before it was discovered that river water could leach out toxins and give them access to the plant's nutrients and health-bearing secrets.

Vital information about which parts of a plant are usable, and how to prepare a medical concoction in safe ratios, comes as second nature to First Nation Australians. Without techniques fresh from the bush and knowledge imparted by word-of-mouth that has kept this medicine alive for millennia, the country's natural contributions to human health might have been lost to time.

Australia's land covers nearly 3 million square miles
© Getty

The taste of kangaroo apples has been compared to melon

© Alamy

Kangaroo apples

When looking for a kangaroo apple, the clue is in its name. This plant has large, green leaves with five pointed fingers, imitating the shape of a kangaroo's paw. The fruit can be found year round, but most typically in the late summer in southern areas of Australia, Tasmania and New Zealand.

Once the plant's small purple flowers fall off, the medicinal properties emerge. These shiny, yellow-orange fruits have been used in Australia for their anti-inflammatory and antioxidant properties for thousands of years. The egg-shaped berries can be crushed and the pulp applied to the skin to soothe aching joints and wounds. The pulp contains a steroid that is involved in the production of cortisone, which reduces inflammation. Though they are often referred to as fruits, they are actually members of the potato family.

Indigenous Australians learned of these beneficial properties, but also came to discover the care that needs to be taken when choosing the fruits to pick. While they improve health when ripe, before this stage they are highly poisonous. The small fruits contain amino acids that increase the production of red blood cells, so that more oxygen can be transported to the site of wounds.

A natural bandage

Growing either as a bush or tree-climbing vine, this hardy plant is embellished with beautiful, delicate yellow flowers. Although these are a treat for the eyes when exploring the Australian bush, it's the leaves and stems that become a real saviour for those in pain.

Taking these parts of the plant and warming them up, they can be crushed together to form a paste. Absorbed by the skin, this salve can relieve inflammation and alleviate pain for arthritis sufferers. The vines are also a traditional cure for headaches. This requires them to be tightly wrapped around the head, creating pressure.

Other traditional uses for these plants include using the sap as an antiseptic and the impressive strength of the stems as rope to carry equipment and belongings with handmade straps.

The snake vine blooms with yellow flowers during spring and summer

Source: Wiki/Biodiversity Heritage Library

Quick tricks for first aid

© Getty

1 Muddy cuts

You might think that mud increases the chance of a wound getting infected, but Aboriginal communities learned which types of soil would benefit fresh wounds. Rubbing it into fresh cuts, the mud acts as a barrier and actually reduces the chance of infection.

© Getty

2 Clay swallowing

Ingesting small amounts of clay as part of your diet can reduce the effects of poisonous plants. If toxins entered the body, ancient Australians knew that eating clay could deactivate them.

© Jody Dav s

3 Desert mushroom

This vibrant, orange mushroom, *Pycnoporus coccineus*, can be sucked on to quickly relieve pain in the mouth, lips and gums. This has been given to babies for use as a teething ring, while also improving oral health.

© Getty

4 Cockroach squeeze

The clear liquid that can be squeezed out of a cockroach's anus has been proven to have both antiseptic and anaesthetic qualities when applied to the skin.

© Getty

5 Tingling nettles

The nettle *Urtica dioica* was traditionally used to reduce the risk of paralysis. By beating the affected area with the nettles, the stinging hairs overstimulate skin receptors. The painful procedure is used to bring back sensation to numbed parts of the body – albeit in a painful way.

Per gram, witchetty grubs contain more protein than beef

© Getty

What's in a witchetty grub?

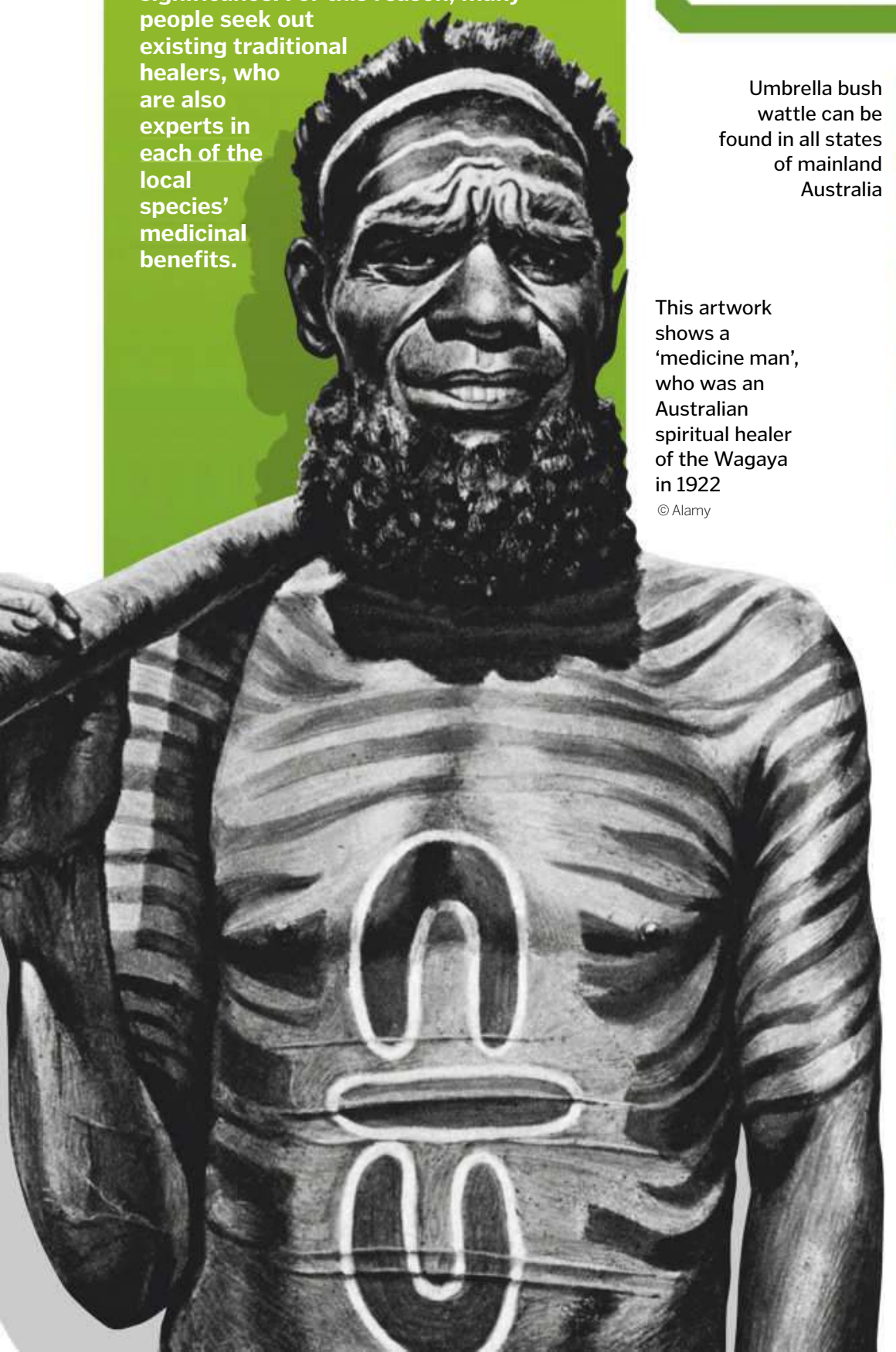
These blubbery squirmers might not be your first point of call in a crisis, but witchetty grubs are packed with nutrition and healing powers. These insects, in their larval stages before turning into moths, are selected as snacks due to their protein-rich contents, healthy fats and vitamin C. They have been a staple of indigenous Australian communities for many years, and are still a popular and important food source today. They can be eaten raw or cooked, providing a quick and easy nutritious meal. The soft parts can are eaten, while the hard head is pulled off.

Aside from being bush tucker, the crawling creatures can be crushed into a paste and used to heal wounds and burns. The properties of the fatty paste mean that it acts as a clean barrier to prevent infection, while the moistness stops the wound from drying out. Witchetty grubs use these healing powers themselves, as when they are cut open, they can rapidly restore their own skin.

Traditional Aboriginal healing

Complementing the Indigenous Australians' traditional healing methods, some use the bond they have with nature to heal their bodies and souls. Using mindfulness and further exploring the strong connection they have to their environment, expert traditional healers within the Aboriginal community assist the ill and suffering. By touching, observing and listening to the animals, plants and water, many believe this can align their spirit and happiness with the assistance of bush medicine.

Western doctors mainly specialise in modern medicine techniques, most of which have been developed using scientific research. For those pursuing full immersion with nature, however, it can be difficult to explain the importance of this healing technique to those less understanding of the cultural significance. For this reason, many people seek out existing traditional healers, who are also experts in each of the local species' medicinal benefits.



This artwork shows a 'medicine man', who was an Australian spiritual healer of the Wagaya in 1922

© Alamy

Umbrella bush wattle can be found in all states of mainland Australia

© Alamy

Bush wattle benefits

Through the trial-and-error process of burning, soaking and chewing this flowering plant, the First Australians uncovered its fruitful benefits. Soaking and boiling the umbrella bush wattle allowed the extraction of hidden gum beneath the bark. This sticky gum relieves the symptoms of sore throats and coughs by coating the throat in gum to protect it from irritation and reducing any inflammation.

This bush wattle was also chosen for burning during smoke therapy – a ritual that combated complications after childbirth, dizziness and nerves. The leaves would be placed over a fire in thick layers. Shortly after giving birth, a woman would lie over them, breathing in the smoke until she began to sweat heavily. This also seemed to stop bleeding after birth. Then the newborn would be briefly held over it as part of the cleansing process, setting the baby up for a healthy start in life.

USEFUL EUCALYPTS

If we take apart the gum trees of the bush, what comforting components can we find?

EUCALYPTUS PIPERITA

© HelloMojo

Active ingredient
Kino resin
Ailment application
Intestinal disorders

Found in the trunk of the Sydney peppermint (*Eucalyptus piperita*) is a multipurpose resin. This can be diluted and drunk to calm inflamed intestines. The material works so well because the stomach can't absorb it. Instead it is slowly absorbed into the intestine.

© Getty

The Sydney peppermint tree's leaves can also be used as a mouthwash to treat the throat and teeth

EUCALYPTUS INCRASSATA

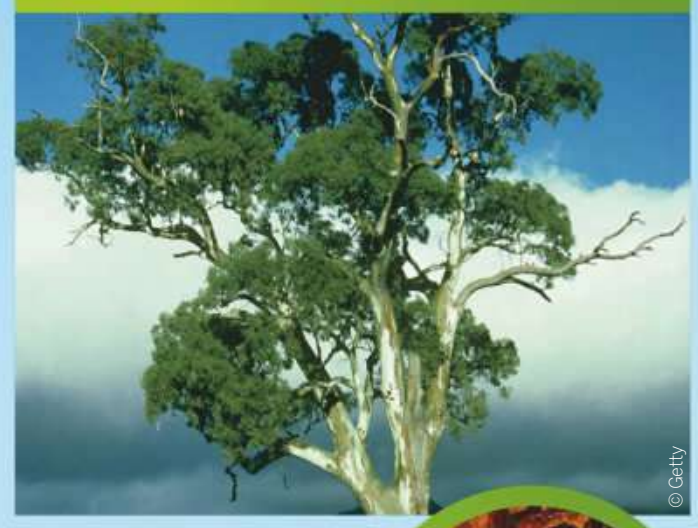
Both images sources: Wiki/Ian Brooker and David Kleinig

Active ingredient
Root water
Ailment application
Dehydration

It is beneficial to know which trees can provide the most water, as the need during droughts is vital. By digging up eight metres of its roots, cutting them into sections and leaving them to drip into a container, one litre of life-saving water can be extracted.

Eucalyptus incrassata can be identified by their small cylindrical fruits

EUCALYPTUS CAMALDULENSIS


© Getty

Active ingredient
Bark gum
Ailment application
Cuts and sores

This tree's bark is bright red when cut. It is the presence of chemicals like polyphenols that create this colour. Polyphenols in the oozing, red gum have antibiotic qualities when combined with air and are traditionally used to protect cuts from infection.

© Getty

Scraping away the bark reveals the red gum

CORYMBIA CITRIODORA

Source: Wiki/Bidgee

Active ingredient
Bark oil
Ailment application
Mosquito repellent

The lemon eucalyptus tree contains oil that has been used to avoid pesky mosquitoes for centuries. Found within the branches and bark, the oil contains a compound called para-Menthane-3,8-diol (PMD) which makes it hard for the insects to detect your scent.

© Alamy

Corymbia citriodora produces white flowers and pear-shaped fruit

CORYMBIA DICHROMOPHLOIA

Source: Wiki/Ian Brooker and David Kleinig

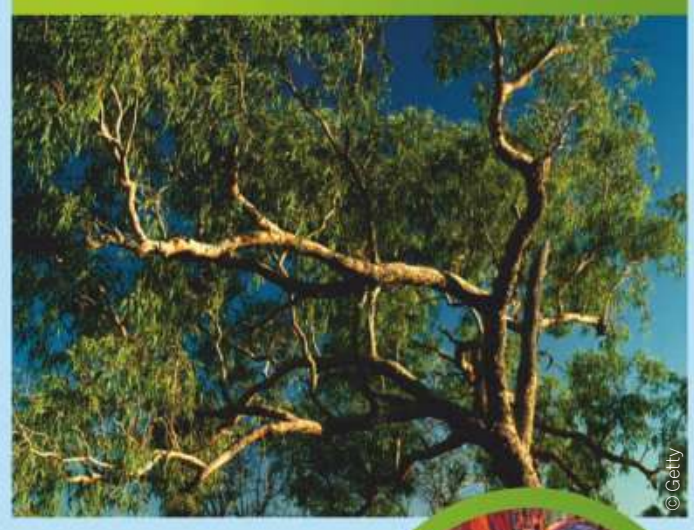
Active ingredient
Nectar
Ailment application
Pulmonary issues

The nectar from this eucalypt was boiled with sugar and water by Aboriginal Australians. This created a medicinal drink that soothes the lungs. It also serves as an effective general anaesthetic for toothache.

© Alamy

This eucalypt is commonly known as the small-fruited bloodwood

EUCALYPTUS MICROTHECA


© Getty

Active ingredient
Inner bark
Ailment application
Snake bites and severe headaches

The bark of this tree can be mashed up into a poultice and applied to snake bites, with antiseptic and disinfectant qualities – very useful in Australia where so many snakes slither about.

© Alamy

Dead bark from the tree needs to be stripped away to find the medicine

DISCOVER DESERTS

What might at first glance appear to be a barren wasteland is actually teeming with life and unique terrain

Deserts cover one-fifth of Earth's surface and are fascinating places. Take the Namib Desert in southern Africa. Considered the world's oldest desert, it has been arid for 55 million years. The Namib reaches the sea along the barren Skeleton Coast, which is named after the shipwrecks that litter the dunes. South of the Skeleton Coast is the Sperrgebiet – which translates as 'prohibited area' – where public access is restricted to prevent diamond hunters combing the coastal dunes for gems.

The Namib is a hot desert, with summer temperatures reaching over 40 degrees Celsius, but deserts can be cold too. For instance, the ice-covered continent of Antarctica is Earth's largest desert. A desert is simply a place where average rainfall amounts to less than 25 centimetres per year. Indeed, some deserts remain rainless for months or even years.

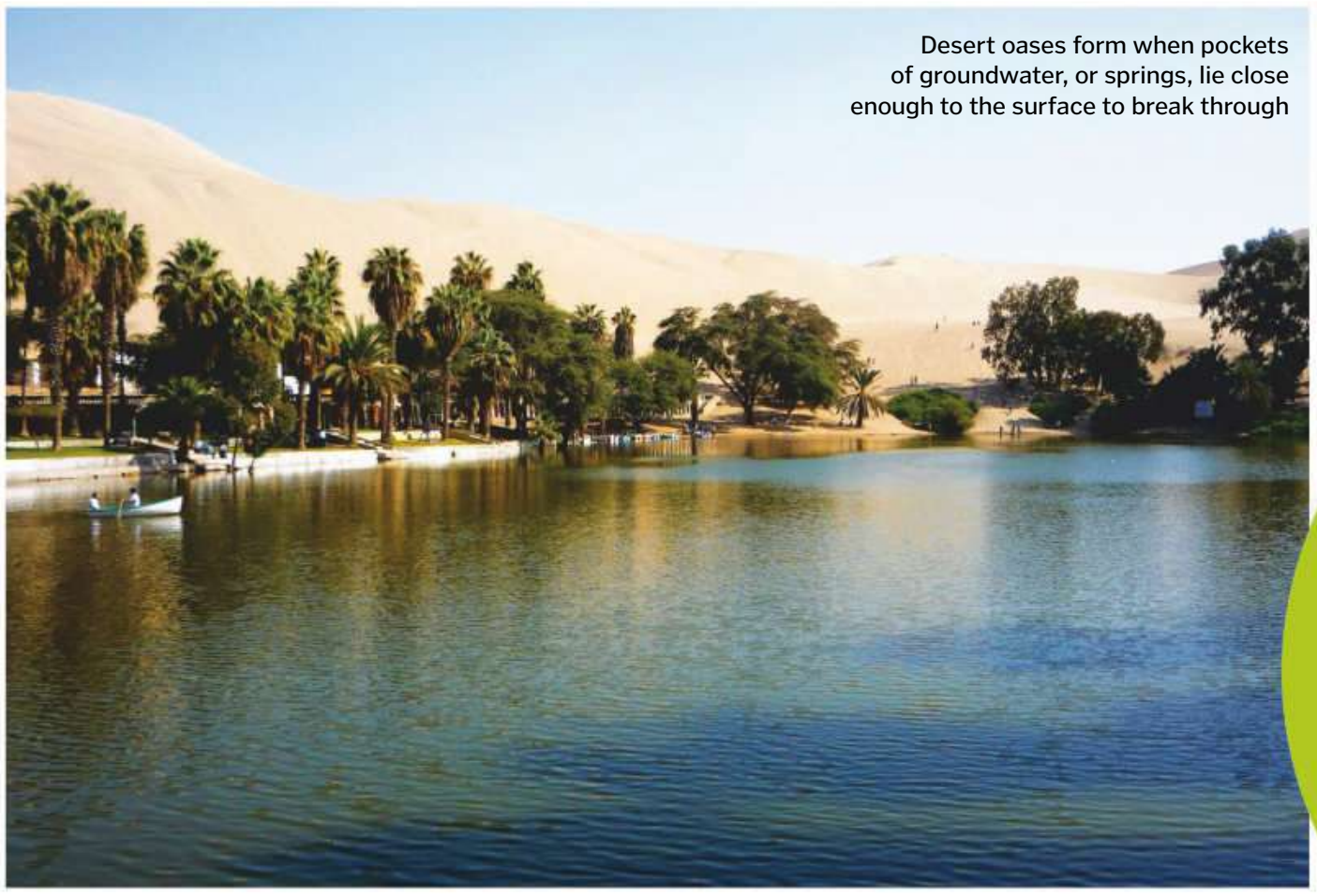
Most of Earth's hot deserts lie within 30 degrees latitude of the equator – either north or south – including Africa's vast Sahara Desert. Gigantic atmospheric currents force air to sink and warm at these latitudes, which in turn suppresses rainfall.

The Namib and Atacama are both coastal deserts lying beside cold ocean currents – the Benguela and Humboldt Currents respectively – that cause air above them to cool. Cold air can hold less water, reducing the rain falling on the nearby warm land. These deserts are among Earth's driest. Most moisture here comes from desert fogs, which form when warm air condenses over the cold ocean. Some deserts in central Asia and Australia lie in continental interiors, so damp ocean air loses most of its moisture before it can reach them.

Desert climates and the wildlife they can host vary drastically from place to place across the world. Hot deserts like the Sahara are warm year-round, and rain is always scarce. Temperatures can reach a sweltering 49 degrees Celsius during the day, but at night can fall to below freezing. Clear skies allow heat to escape after sunset, and small mammals forage at dusk. Plants include ground-hugging shrubs with leathery leaves.

© SPL

An elf owl – the world's smallest owl – peeking out its nest in a saguaro cactus



Desert oases form when pockets of groundwater, or springs, lie close enough to the surface to break through

In semi-arid deserts like the Great Basin Desert, which spans a large part of Nevada and extends into western Utah, eastern California and Idaho, temperatures rarely fall below ten degrees Celsius or rise above 38 degrees Celsius. Spiny plants like the creosote bush and sagebrush thrive in this climate.

Close to cold ocean coasts, desert summer temperatures rarely rise above 24 degrees Celsius and yearly rainfall can be 13 centimetres. Plants have roots close to the surface to collect rain, and have fleshy, water-storing stems. Some toads remain dormant in burrows for months between rainstorms.

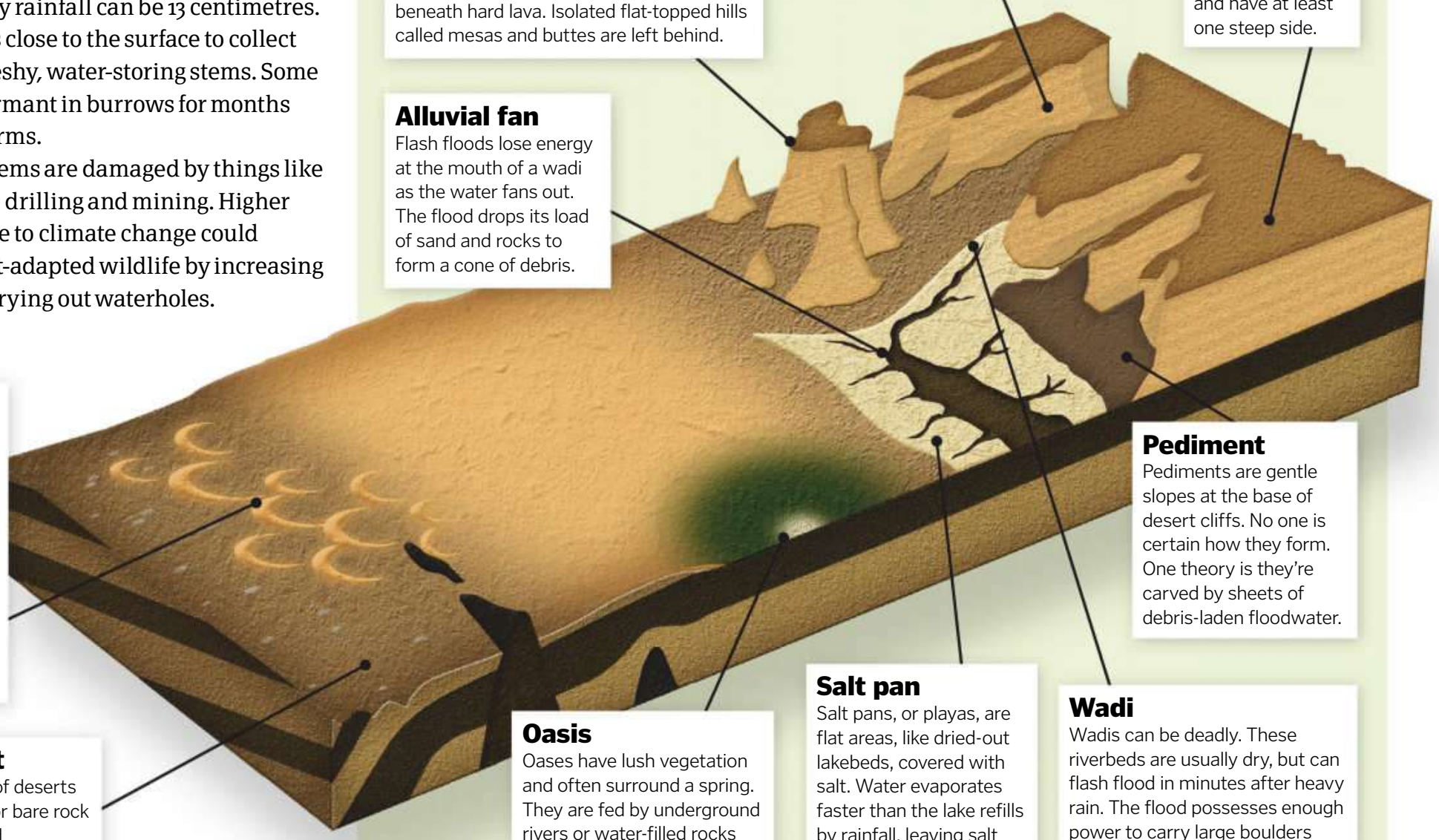
Desert ecosystems are damaged by things like off-road vehicles, drilling and mining. Higher temperatures due to climate change could threaten drought-adapted wildlife by increasing fires, as well as drying out waterholes.

Earth's make-up

Of the 30 per cent of Earth that is land, desert accounts for one-fifth of that terrain

Explore desert landscapes

Dunes aren't the only desert terrain. Learn about salt pans, oases, wadis and more



Canyon
Desert canyons form over millions of years. Rock, sand and water carried down wadis by flash floods cut deep channels into a plateau.

Plateau
Plateaux are large, flat highlands that rise more than 457 metres above their surroundings and have at least one steep side.

Mesas and buttes
Flash floods wear away the bare sides of plateaux where soft sedimentary rocks lie beneath hard lava. Isolated flat-topped hills called mesas and buttes are left behind.

Alluvial fan
Flash floods lose energy at the mouth of a wadi as the water fans out. The flood drops its load of sand and rocks to form a cone of debris.

Dune field
Dunes cover about 25 per cent of Earth's deserts. The diagram shows barchan dunes towards the edge of the dune field. Barchans form when sand is scarce – less than ten metres deep.

Rocky desert
Nearly 75 per cent of deserts are stone-covered or bare rock plains. Rainfall, wind, temperature and rock type affect how the desert looks.

Oasis
Oases have lush vegetation and often surround a spring. They are fed by underground rivers or water-filled rocks that sit close to the surface.

Salt pan
Salt pans, or playas, are flat areas, like dried-out lakebeds, covered with salt. Water evaporates faster than the lake refills by rainfall, leaving salt and minerals behind.

Pediment
Pediments are gentle slopes at the base of desert cliffs. No one is certain how they form. One theory is they're carved by sheets of debris-laden floodwater.

Wadi
Wadis can be deadly. These riverbeds are usually dry, but can flash flood in minutes after heavy rain. The flood possesses enough power to carry large boulders and sweep people away.

Life at the extremes

Facing scorching days, freezing nights and little water, hot deserts are hard to survive, but lots of wildlife call them home

The spotted hyena is the largest of the three subspecies and is a very bold and resourceful scavenger

Camel
Camels can drink an incredible one-third of their body weight in ten minutes, and store water by diluting their blood. They chew thorny plants with their thick lips. Their fat-filled humps both insulate them against the beating Sun and serve as a source of energy during food shortages.

Addax
Addaxes are Earth's most desert-adapted antelopes. Broad, flat-soled hooves stop them sinking into sand, while their brown coats turn white in summer to reflect sunlight and keep them cool. Addaxes search the Sahara for grasses and shrubs to eat, which provide all the water they need.

Spotted hyena
Spotted hyenas are Africa's most common large carnivore and live in semi-deserts. They thrive by scavenging almost anything, including putrid meat, cooked porridge, animal droppings, bones and vegetables. Powerful jaws and stomach acid allow them to digest all parts of an animal except the hair and hooves.

Welwitschia plant
Welwitschia are leathery succulent plants that rely on desert fog and dew for water. Found along the Namib Desert coast where no rain falls in some years, they collect fog through numerous tiny pores on their leaves. Their long taproot can reach underground water too.

Kangaroo rat
Kangaroo rats never need to drink. Their kidneys extract water from their food, which includes insects, grass, leaves and seeds from creosote bushes. To make dry seeds succulent, they store them in humid burrows to absorb water.

Black-tailed jackrabbit
Black-tailed jackrabbits are hares, not rabbits. They have black-tipped ears, which can grow up to 20 centimetres; these lose heat to keep the animal cool. Jackrabbits shelter from the Sun in hollows beneath shrubs or grass and forage in the cool of evening.

ON THE MAP

The biggest deserts in the world
1. Antarctica (5.5 million square miles)
2. Sahara Desert (3.6 million square miles)
3. Australian deserts (1 million square miles)
4. Arabian Desert (716,400 square miles)
5. Gobi Desert (500,000 square miles)
6. Kalahari Desert (350,000 square miles)
7. Patagonian Desert (221,191 square miles)
8. Syrian Desert (200,000 square miles)
9. Chihuahaum Desert (193,783 square miles)
10. Great Basin Desert (190,000 square miles)

Roadrunner
Roadrunners aren't ditzy or blue, but are well-named, as they sprint from danger at 20 miles per hour. To save energy, they cool down at night, and they warm up by turning their backs to bathe in morning sunlight.

Saguaro cactus
The saguaro is North America's largest cactus and can reach 15 metres tall and weigh six tonnes. Cactuses are botanical water balloons. Expandable ribs support each plant's pulpy body, allowing it to inflate to store rain. To reduce water loss, they have no leaves. Spines protect them from predators.

Creosote bush
Creosote bushes in the Mojave Desert could be Earth's oldest living plants – perhaps 11,700 years old. Creosotes grow in US deserts and can survive two years without rain. Small, waxy leaves reduce moisture loss and drop off during dry periods. These shrubs only flower after rain.

Thorny devils are found throughout Australia's vast, arid interior

Thorny devil
Thorny devils catch morning dew and rainwater in tiny grooves between the scales on their belly and legs. They can gather as much as one gram during a rainstorm. The lizard gulps to move water from the channels up into its mouth.

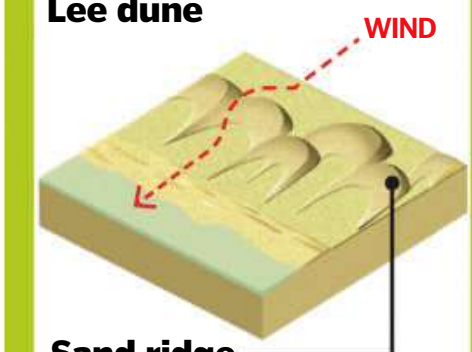
Meerkat
Meerkats absorb heat on cold mornings by exposing their dark bellies, which have little hair. Like many desert animals, they get all their water from food. Dark circles around their eyes reduce glare from the Sun, while a special membrane across their eyes keeps out any sand in the air.

Fearless meerkats will often make a meal of snakes and scorpions

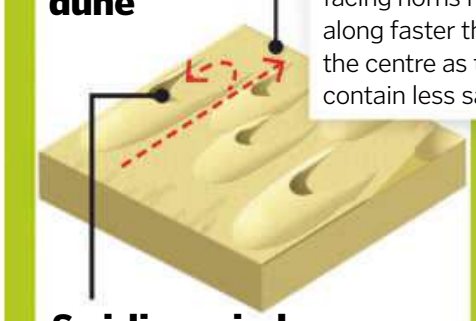
Sahara Desert ant
One of Earth's most heat-tolerant insects, these ants withstand surface temperatures of 60 degrees Celsius. Long legs raise their bodies above hot ground, and they sprint to minimise sunlight exposure. Desert ants count their footsteps to avoid getting lost instead of leaving a chemical trail, which would evaporate.

"Thorny devils catch morning dew and rainwater in grooves between scales on their belly and legs"

Sand dunes
Almost 99 per cent of Earth's active dunes are in deserts, but how do they form?

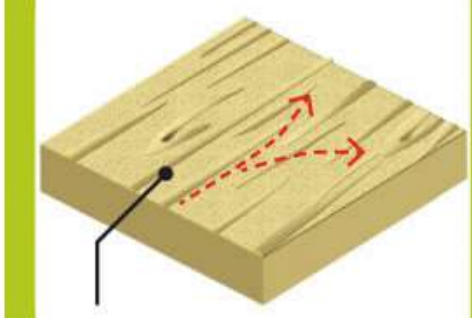
Lee dune


Sand ridge
Wind eddies when it blows over and around a rock. Windblown sand is dropped on the downwind side.

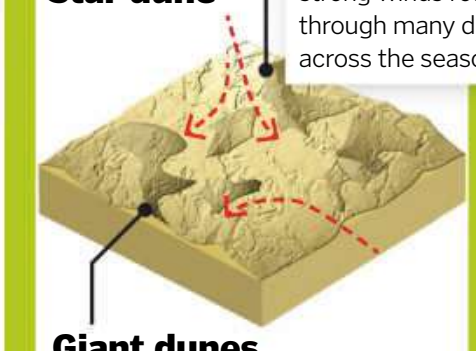
Barchan dune


Horns
The downwind-facing horns race along faster than the centre as they contain less sand.

Swirling wind
The downwind side of the dune is steepened by eddies formed when wind overshoots the dune crest.

Linear dune


Wind changes direction
Linear dunes form when steady winds blow from two different directions. Sand moves parallel to the crest.

Star dune


Seasonal winds
Star dunes form when strong winds rotate through many directions across the seasons.

Giant dunes
Star dunes can reach over 500 metres tall. The rotating winds pile sand higher instead of blowing the dune along.

ANTARCTICA'S MELTDOWN

Why Earth's frozen continent is shedding so much ice

Words by **Scott Dutfield**

It's the coldest place on the planet, but a hot topic when it comes to the climate crisis. Antarctica is a massive continent where 90 per cent of the world's ice can be found. For more than 100 million years, however, the continent covering the South Pole was a tropical haven, before a dramatic climatic shift stripped it of its lush green surface and replaced it with an icy coat around 34 million years ago. Since then the Antarctic has become a frozen behemoth, with an average surface ice thickness of 2,160 metres and temperatures that can plummet to below -80 degrees Celsius. It's made up of two distinct parts, East and West Antarctica, spanning a total of 5.4 million square miles.

This frozen land regulates the Earth's global temperature through a natural process called the albedo effect. White surfaces, such as the Antarctic snowscape, reflect incoming solar radiation. In doing so, the heat generated by the radiation is sent straight back into space. In contrast, darker surfaces such as soil and concrete absorb the solar radiation and heat. Without Antarctica, all that reflected heat would be absorbed, rapidly raising the global temperature of the planet. Although the albedo effect makes Antarctica so vital, it's also one of the reasons it's shrinking.

Ever since the early 1900s, glaciers and ice sheets around the world have been melting at an accelerated rate, with the blame falling predominantly on the actions of humankind – particularly since the rise of heavy industry.

From the mid-18th century, Europe and America erupted in the smoke and smog of the Industrial Revolution. Ever since, mass manufacturing around the world has continued to throw damaging gases into the

© Getty

Despite losing ice, Antarctica is home to a growing population of gentoo penguins

© NASA's Goddard Space Flight Center

An artist's concept of ICESat-2 using a laser to measure elevation on Earth's surface

Keeping an eye on ice

The best way to keep tabs on how much of Antarctica's ice is melting into the ocean is from space. Satellites such as NASA's Ice Cloud and land Elevation Satellite-2 (ICESat-2) have discovered that the thickness of Antarctica's ice has been thinned by as much as 20 per cent since the first ICESat mission was completed in 2009. ICESat-2 can determine this using a laser altimeter that uses light to measure height on the surface. It sends 10,000 pulses of light every second to Earth and then records how long it takes for the light to bounce back and reach ICESat-2. This information, along with data from other similarly laser-equipped satellites such as the European Space Agency's CryoSat-2, is used to calculate changes in ice thickness.

235 animal species call Antarctic waters and land home

Record-breaking temperatures

On 6 February 2020, the Esperanza Base weather station at the northern tip of the Antarctic Peninsula detected that temperatures had soared to 18.3 degrees Celsius, the hottest ever recorded in Antarctica. This was due to warm tropical air moving across the Southern Ocean to melt the ice. These winds would normally be blocked by a group of strong westerly winds that band around the Southern Hemisphere. However, they are thought to have been in a weakened state at the time, allowing the tropical winds to reach the peninsula. It resulted in 20 per cent of regional snow accumulation on the peninsula's Eagle Island to be lost in a single event.

4 February 2020: Eagle Island's peak temperature on this day equalled the temperature in Los Angeles at the same time

13 February 2020: As a result, Eagle Island rapidly lost about 106 millimetres of snow

© NASA Earth Observatory/Joshua Stevens

7.2 million cubic miles of ice contained on the ice sheet

© Getty

atmosphere. Burning fossil fuels, such as coal and natural gas, releases gases that subsequently melt ice away from Antarctica through global warming. These greenhouse gases, such as carbon dioxide, insulate the planet by absorbing or trapping the solar heat Antarctica so effectively works to reflect. This then increases the global temperature and directly causes our world's ice to melt, including Antarctica's.

Other studies suggest that a change in the winds may also be playing a part in the Antarctic's continued ice loss, particularly in the West Antarctic regions. Historically, winds have blown across the warmer waters of the neighbouring Amundsen Sea towards the west. This helps keep them from reaching the vulnerable protruding glaciers on Antarctica's coast. However, recent reports say that those winds are now alternating more between the east and west, allowing warm Amundsen water to melt away glaciers when it moves east. The changes in the winds are thought to again be the result of global warming, which influences air pressure and wind patterns. It's estimated that 118 gigatonnes of the Antarctic ice sheet are lost per year as a result, which comes with serious global issues.

Arguably the largest threat from a continuously melting Antarctica is the rise of global sea levels. This increases the risk of coastal erosion and flooding, ultimately reducing the amount of liveable land. Since 1880, mean global sea levels have risen by 21 to 24 centimetres, and are predicted to increase a further 20 to 30 centimetres by 2050. This increase will directly affect 300 million people around the world, with some reports suggesting that by 2100 land currently occupied by 200 million people will sit below the high-tide line. Along with land loss, melting Antarctic ice also affects the temperature and currents of the world's oceans and shifts global weather patterns.

Although there's no denying that Antarctica's current meltdown is one of the greatest threats humankind faces, many countries around the world are making changes that can have a positive knock-on effect on Antarctica. It's predicted that the threshold for irreversible loss to the West Antarctic ice sheet would be the result of a global average warming of 1.5 to 2 degrees Celsius. Global environmental accords, such as the Paris Agreement, aim to lower global average warming through emission controls and renewable energy investment, to try and save the icy continent.

Krill populations around Antarctica have declined by more than 80 per cent since the 1970s

© Getty

© Getty

Antarctica is roughly the area of the United States and Mexico combined

If Antarctica's ice sheet melted, sea levels would rise by 60 metres

CALVING ICEBERGS

Where's all the ice going and what's causing it to melt?

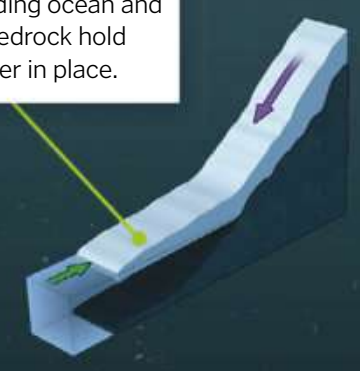
West Antarctica
This part of Antarctica holds six per cent of the world's fresh frozen water and loses billions of tonnes of ice through glaciers.

Pine Island Glacier
Since 2012 the most vulnerable of all Antarctica's glaciers has been shedding 58 billion tonnes of ice every year into the Amundsen Sea. This makes it the biggest single contributor to the rise in global sea levels.

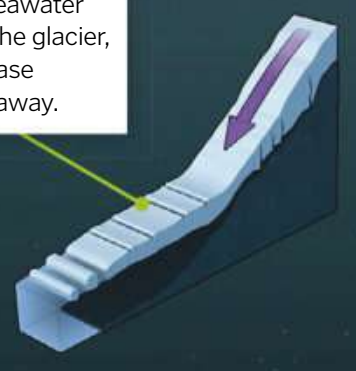
Thwaites Glacier
Also known as the 'doomsday glacier', this block of ice is one of the most vulnerable glaciers to rapid melting. The melting of the 74,000 square mile glacier already accounts for four per cent of global sea rise.

HOW A GLACIER MELTS

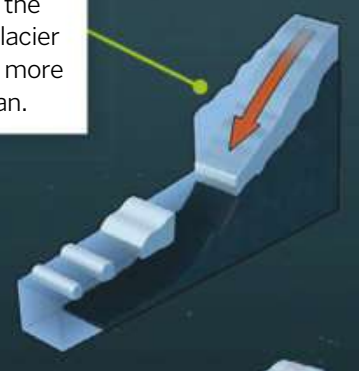
FROM THE TOP



Solid
Surrounding ocean and sturdy bedrock hold the glacier in place.



Cracking
Warm air and seawater form cracks in the glacier, and ice at the base begins to drain away.

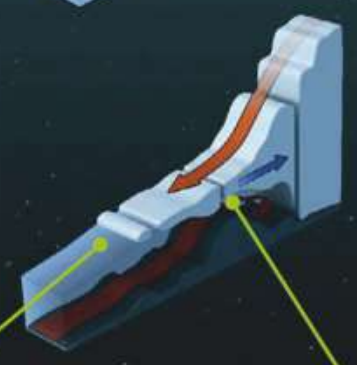


Slippery slope
As more ice is lost the steepness of the glacier increases, causing more to fall into the ocean.

East Antarctica
The largest of Antarctica's two ice sheets, East Antarctica makes up two-thirds of the entire continent, has roughly nine times the volume of ice of West Antarctica and averages around 1.6 miles thick.

FROM THE BOTTOM

Stuck on rock
Glaciers are anchored to a marine basin, while miles of ice floats on the ocean surface.



Retreat
Warm waters beneath the ice's surface erode when the glacier is anchored by the marine basin, called the grounding line.

Sinking
As more and more basin is eroded, less ice is held on the shelf, allowing it to sink into warmer waters and melt.

The average temperature at the coast is -10 degrees Celsius

Beneath the ice
Channels of water have been discovered flowing beneath the continent's ice sheet, which can help ice to move out to shore.

Ross Shelf
Ross Ice Shelf is the world's largest body of floating ice, currently estimated to have an area around 182,000 square miles.

AR ZONE! SCAN HERE

Illustration © Nicholas Forder

Deep-diving sperm whale

How does a mammal the size of a bus survive great depths?

Sperm whales are rather odd-looking creatures. They have the biggest head and brain in the animal kingdom, which looks out of proportion to the rest of the body, and is much more noticeable in males. They also have a narrow, long lower jaw. Sperm whales are mammals that, just like us, need to breathe air. Unlike us, they are very well adapted to life in deeper waters. At depth in the ocean, pressure increases and volume decreases, but that doesn't bother these whales. They can dive down to depths of more than 2,200 metres – that's the same as about 22 full-size football pitches.

Sperm whales are found in deep offshore waters of all the world's oceans. It's quite unusual to see them in shallower waters, but it can happen and when it does, it generally means something isn't quite right and the animal has lost its way. Out in the ocean they can often be found where there are deep canyons to feed on giant squid, so it's no wonder they are deep-diving specialists.

They have a range of incredible adaptations to make diving so deep possible: from techniques to stop nitrogen being absorbed into their blood, which could lead to 'the bends', to conserving oxygen for when they need it the most. They can disappear under the water and won't be seen again for up to two hours, but 45 minutes is more common. When they resurface, look out for a really distinctive bushy blow of air that travels forwards and to the left of the animal's head.

A sperm whale: the biggest of all the whales with teeth

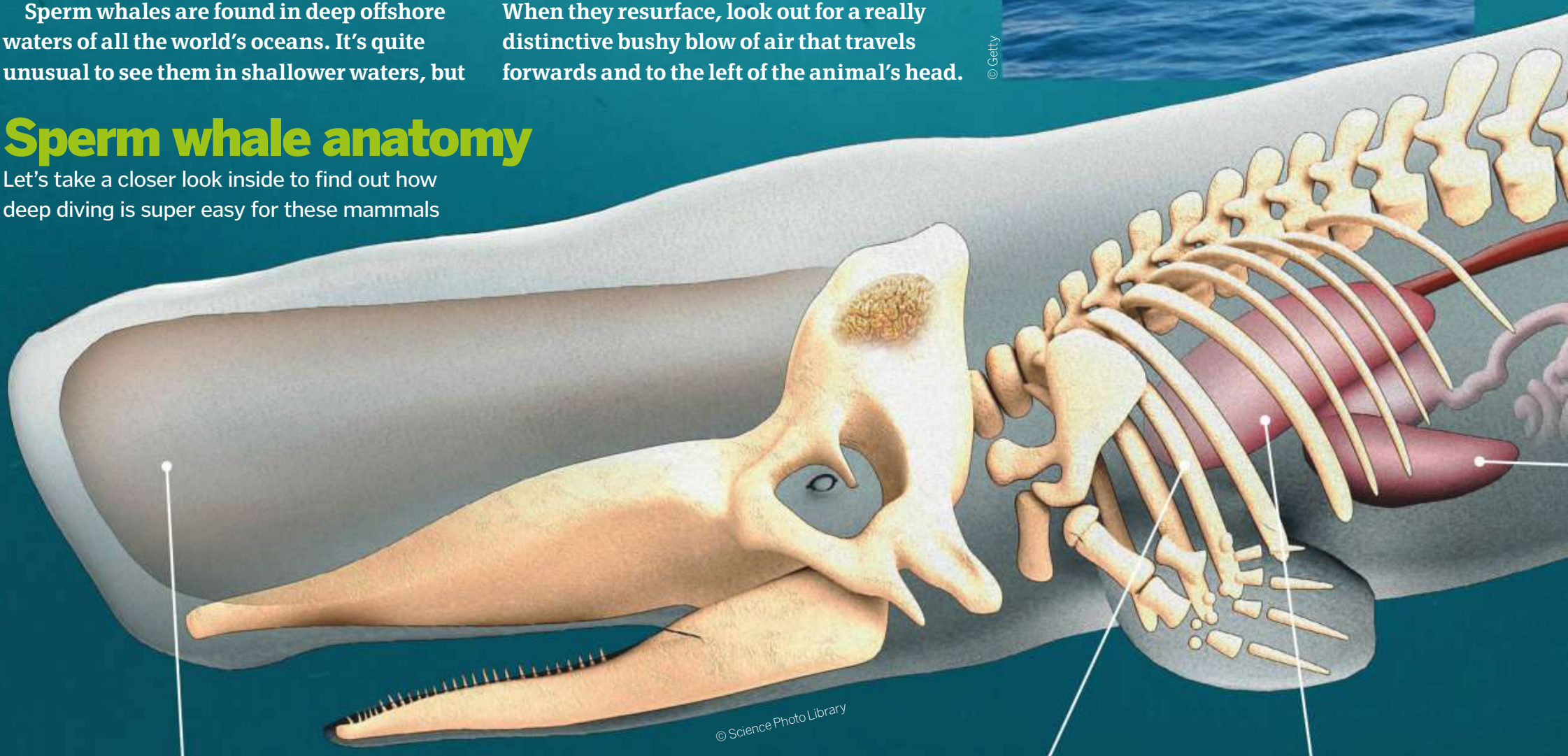
© Getty

A sperm whale returning to the surface from the depths to breathe

© Getty

Sperm whale anatomy

Let's take a closer look inside to find out how deep diving is super easy for these mammals



© Science Photo Library

Buoyancy
Their huge heads hold a waxy substance called 'spermaceti' which may help with buoyancy – and gives them their name.

"They are very well adapted to life in deeper waters"

Flexible body
Rib cages and lungs can collapse easily at depths where pressure is high.

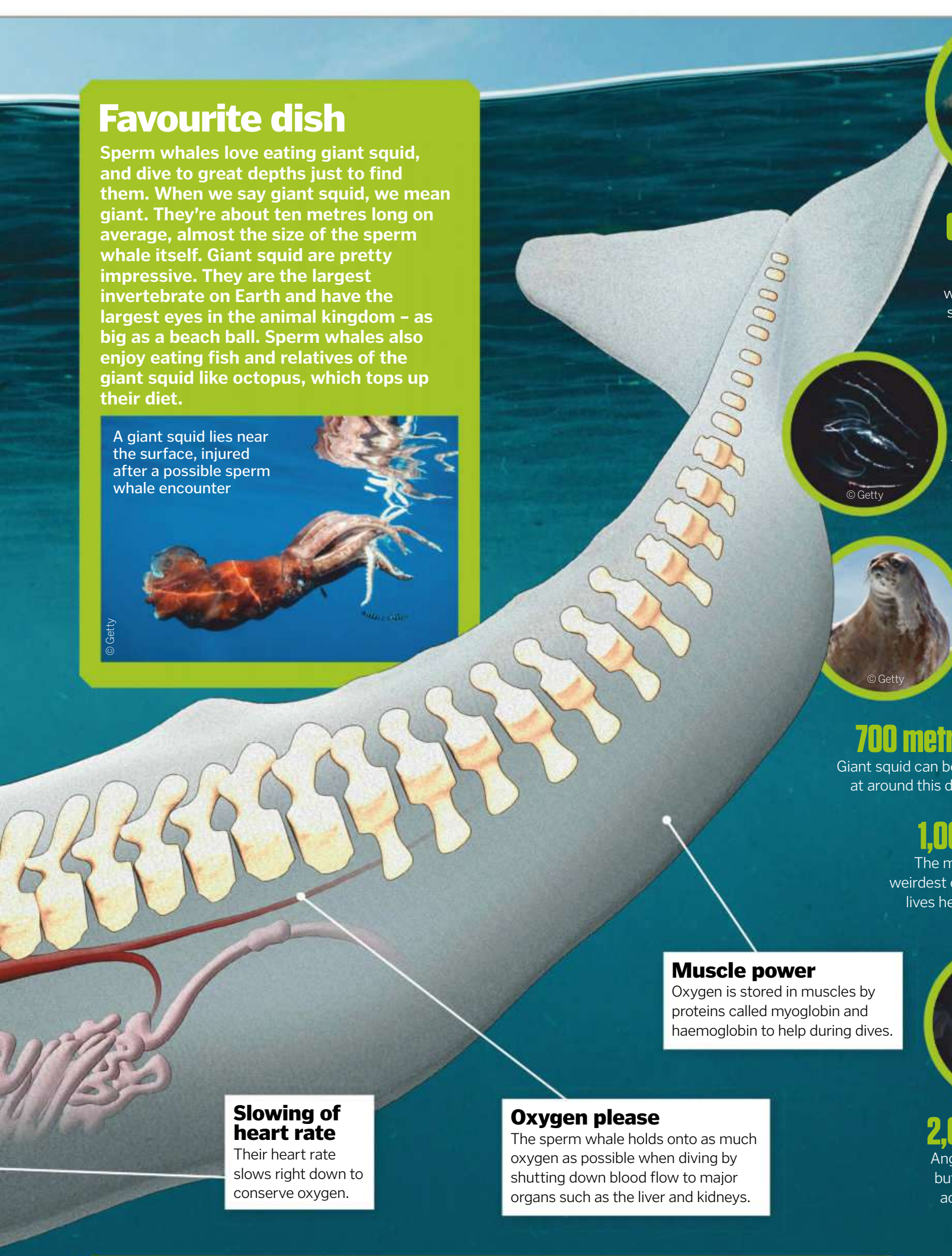
Preventing the bends
Pressurised air in the lungs is forced away from air sacs that would transfer excess nitrogen into the blood.

Favourite dish

Sperm whales love eating giant squid, and dive to great depths just to find them. When we say giant squid, we mean giant. They're about ten metres long on average, almost the size of the sperm whale itself. Giant squid are pretty impressive. They are the largest invertebrate on Earth and have the largest eyes in the animal kingdom – as big as a beach ball. Sperm whales also enjoy eating fish and relatives of the giant squid like octopus, which tops up their diet.

A giant squid lies near the surface, injured after a possible sperm whale encounter

© Getty



Muscle power
Oxygen is stored in muscles by proteins called myoglobin and haemoglobin to help during dives.

Slowing of heart rate
Their heart rate slows right down to conserve oxygen.

Oxygen please
The sperm whale holds onto as much oxygen as possible when diving by shutting down blood flow to major organs such as the liver and kidneys.

Into the depths

© Getty

0 to 1 metres
Basking sharks can filter the equivalent water of one Olympic-sized swimming pool every hour.

© Getty

400 metres
Animals produce their own light called bioluminescence to survive in the dark.

© Getty

600 metres
Weddell seals are expert divers.

700 metres
Giant squid can be found at around this depth.

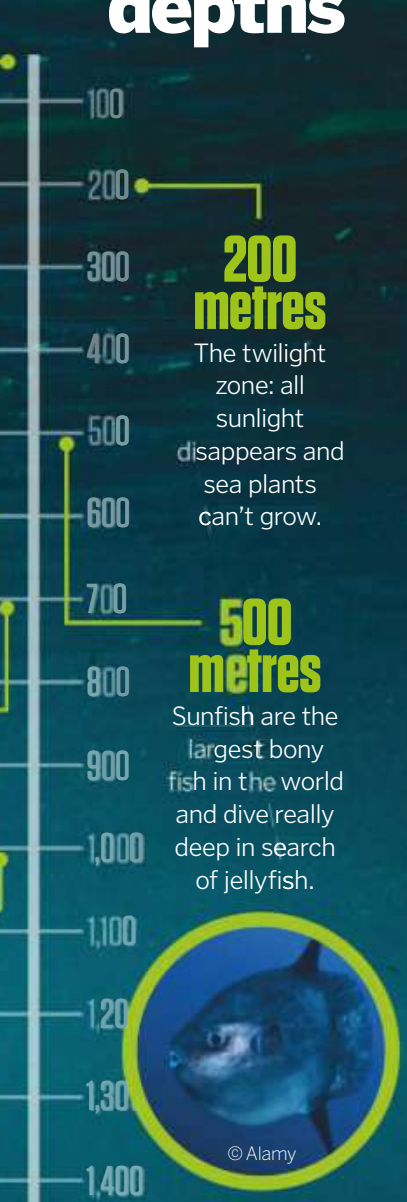
1,000 metres
The midnight zone: the weirdest creatures spend their lives here in full darkness.

© Alamy

2,000 metres
Anglerfish look scary, but they're very well adapted to survive with no light.

© Getty

2,250 metres
The sperm whale can dive to great depths using echolocation to track down meals.



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200 metres
The twilight zone: all sunlight disappears and sea plants can't grow.

500 metres
Sunfish are the largest bony fish in the world and dive really deep in search of jellyfish.

© Alamy

2,992 metres
Cuvier's beaked whale is the world's deepest-diving whale.

What about us?

A diver needs specialist equipment to help them breathe underwater, but can only go to 40 metres, which in comparison to the sperm whale is nothing. When underwater, the extra pressure on the human body means gases – oxygen and nitrogen – are dissolved into the blood and tissues. We like the oxygen, but it's the nitrogen that can be a problem, particularly if you come up from depth quickly. Instead of the nitrogen releasing slowly from less pressure, it forms bubbles in the bloodstream that expand as the pressure drops. This causes something called 'the bends' and can restrict blood flow to major organs. It's the nitrogen in our body that limits us to how deep we can dive and for how long using traditional diving kit, as well as the air supply.

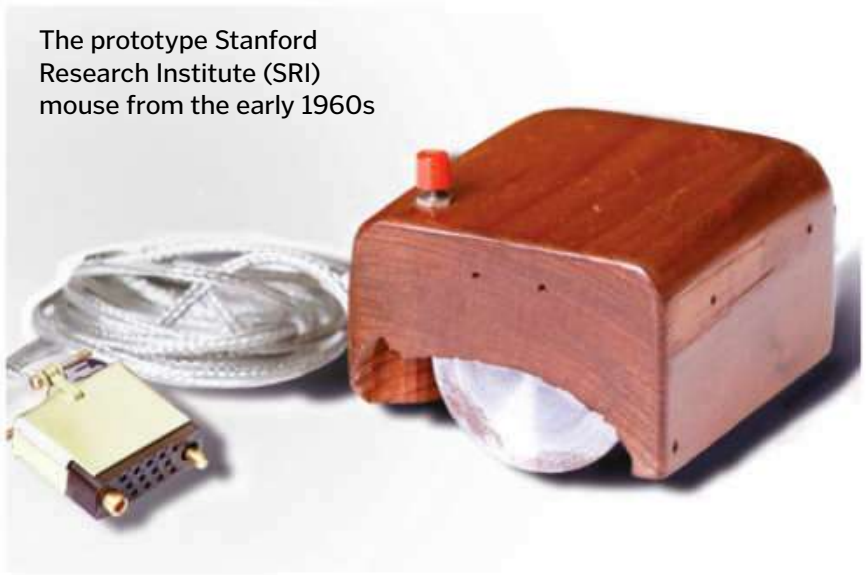
© Getty

A diver in scuba gear exploring the underwater world

HOW SPACE TECH BENEFITS EARTH

Discover some of the inventions made for space exploration that we now use every day

Words by **Scott Dutfield**



The prototype Stanford Research Institute (SRI) mouse from the early 1960s

© SRI International

A computer mouse resembles the tiny mammal, with a cable for a tail

© Getty

A MOUSE FROM SPACE

When you purchase a desktop computer, a mouse will usually also be included. However, that wasn't always the case. The mouse was created by American engineer Doug Engelbart back in the late 1960s for the Stanford Research Institute. Engelbart's research was funded by NASA, who hoped to make computers, which at the time were being used as flight control systems and for simulations, more interactive. What Engelbart created was a handheld device that used two perpendicular wheels that were turned by pushing the mouse on the flat surface below it.

The movement of these wheels would then move the cursor on the computer screen. Engelbart presented the new 'mouse' at the Fall Joint Computer Conference in San Francisco in 1968, where thousands of engineers witnessed it for the first time. Since then the humble mouse has undergone several upgrades, with trackpads and laser tracking becoming the new normal.

"NASA hoped to make computers more interactive"

Inside an optical mouse

How these computer companions move a cursor on the screen

Scroll wheel
This rolling wheel is connected to a switch mechanism that tracks the direction of movement and how much the wheel has rotated.

Microswitches
Two switches either side of the scroll wheel register when you click the mouse's right and left buttons.

Cable
The digital signals generated by the chip are sent via the cable – or by Bluetooth for wireless versions – to the computer to move the cursor.

Light-detector chip
This chip measures the light reflected back from the desk and converts the movements into signals that are sent to the computer to move the cursor.

Light
An LED bulb produces the red light which is used to track the movement of the mouse using a detection chip.

© Alamy

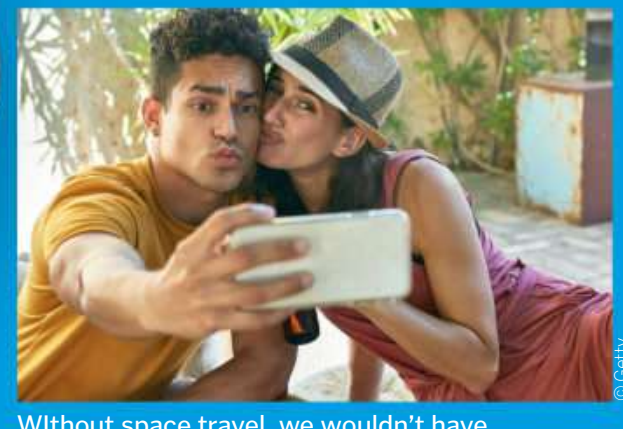
The first camera phone was the Kyocera VP-210, released in 1999

© Getty

SELFIE SCIENCE

It's hard to imagine that mobile phones ever existed without a camera. That was until American physicist Eric Fossum created the pixel image sensor, paving the way for modern-day smartphone cameras and webcams. It was created in NASA's Jet Propulsion Laboratory back in 1993. The intention was to invent cameras small enough for interplanetary space travel. However, Fossum's 'camera-on-a-chip' technology quickly proved valuable for many different industries, including the invention of the camera phone.

The camera in your smartphone evolved from Fossum's original complementary metal-oxide-semiconductor (CMOS) active pixel image sensor. The sensor works using an array of pixel sensors covered by colour filters and a photodiode – a device that converts light into an electrical current. As light passes over the surface of the sensor, it is detected and converted into an electrical signal before it is amplified by several transistors. These signals are then interpreted as an image.



© Getty

WIthout space travel, we wouldn't have the selfie

CREATING CLEAN AIR

There's probably never been a time where clean air has been as important as it is today, with some air purifier makers claiming more than a 50 per cent rise in sales during 2020. But some air-purification technology was first developed to stop space crops from harming astronauts. Back in the 1990s, NASA conducted research into removing the build-up of natural gases emitted from plants, called ethylene. This was important research for establishing the possibility of having plants for food aboard crewed spacecraft during interplanetary travel.

On Earth ethylene is harmless, but in an enclosed spacecraft it can build up and cause health issues for astronauts. Engineers created ethylene 'scrubbers' to take the gas out of the air and convert it into useful by-products. The process works by drawing the air surrounding the plants into tubes coated with titanium dioxide. When a UV light is passed over the titanium dioxide, the ethylene in the air is converted into water and carbon dioxide, which can be reused to maintain the plant's growth. Following its development, this technology has been widely adapted to remove particles, bacteria, viruses and mould from the air.

Mizuna lettuce growing aboard the ISS
© NASA

262,400 solar cells which cover an area of around 2,500 square metres are used to power the ISS
© NASA

SOLAR ENERGY REPOWERED

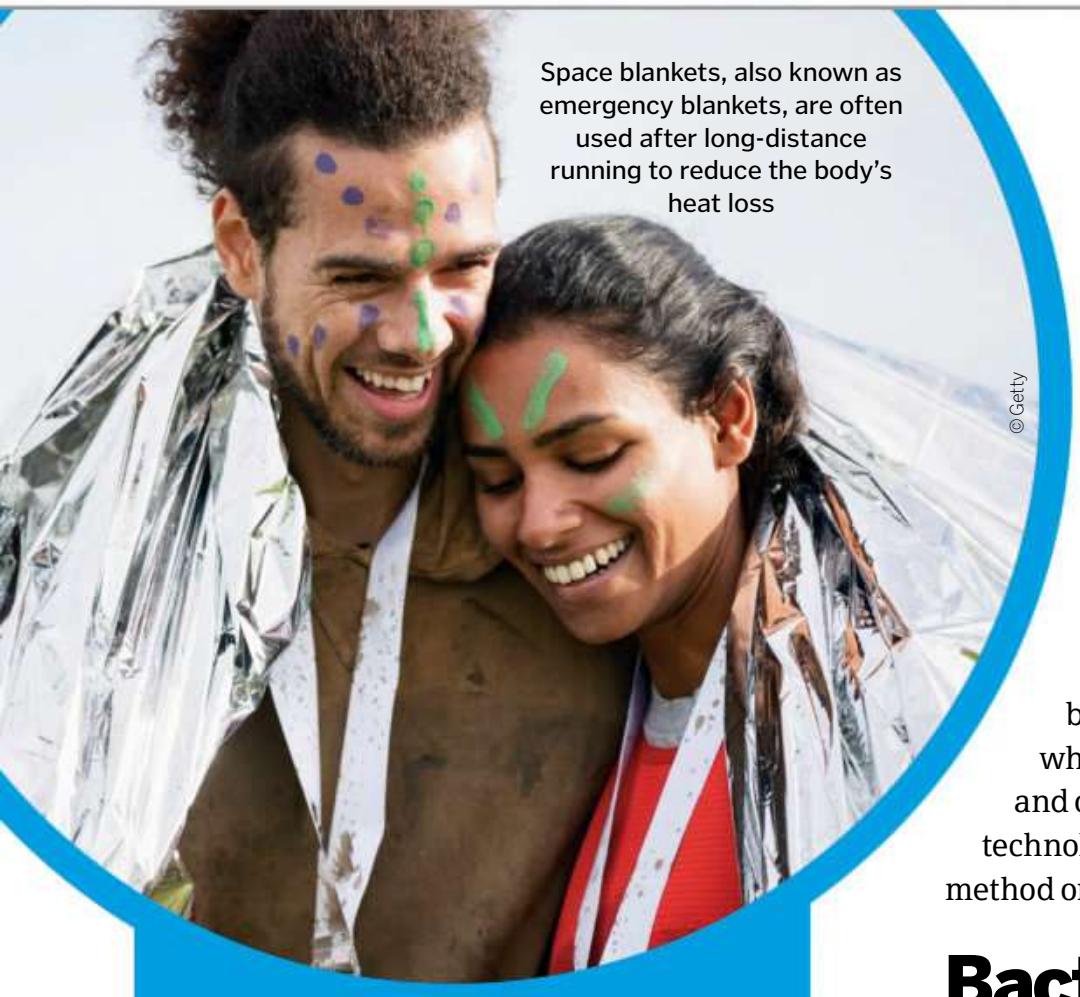
Although solar power cells were not invented by NASA, nor were they exclusively created for space exploration, research conducted in part by NASA propelled their development. This research began in the early 1980s and was intended to support the launch of the International Space Station (ISS). Without a charging cable to connect it to Earth, the ISS requires solar energy collected from the Sun. However, at the time solar cells were not ready for space travel, so NASA partnered with a company known today as PowerFilm. Together they created paper-thin solar cells that were flexible enough to be rolled up and light enough to be sent to the ISS. This solar film can convert 90 per cent of the light that crosses its surface into energy. The technology paved the way for more lightweight and efficient solar panel production on Earth.

© Alamy

Once known as 'slow spring back foam', temper foam returns to its original form after any applied pressure is removed

FOAM THAT REMEMBERS

Initially designed to improve the seat cushioning and crash protection of airline pilots and passengers, memory foam, also known as temper foam, was a NASA creation from the 1960s. An engineer called Charles Yost had worked on the development of a recovery system for the Apollo Command Module back in 1962 and was later drafted by NASA to work on airline seating for crash protection. The result was a polymer-plastic material that could absorb a lot of energy from an impact but remain soft. The cushion-like material proved successful in air travel and exploded into other industries. Temper foam mattresses and other memory foam products hit the commercial market back in the early 1990s, and since then have diversified for use in hospitals, as shoe soles and even as a lining in American football players' helmets.



Space blankets, also known as emergency blankets, are often used after long-distance running to reduce the body's heat loss

© Getty

SPACE BLANKETS

These foil blankets are often seen on the backs of marathon runners or incorporated into outdoor and camping products, but their initial use was to save a long-lost space station. During its launch in 1973, Skylab, America's first space station, lost one of its solar shields and began to overheat, reaching temperatures of around 54 degrees Celsius. To tackle this, NASA used thin metallic sheets to deflect heat.

Scientists created a metallic parasol that was taken into space aboard a crewed mission and attached to Skylab, ultimately preventing it from overheating and destroying the equipment on board. The lightweight material has not only been used on other spacecraft and satellites since Skylab, but has been used to create warming space blankets. Even though they were initially created to reduce heat, they are also good for keeping our bodies warm. These blankets trap up to 90 per cent of the body's naturally produced heat, which would normally be lost to the environment, thus keeping our bodies warm.

© Alamy

Skylab was launched as proof of concept that humankind could live in space

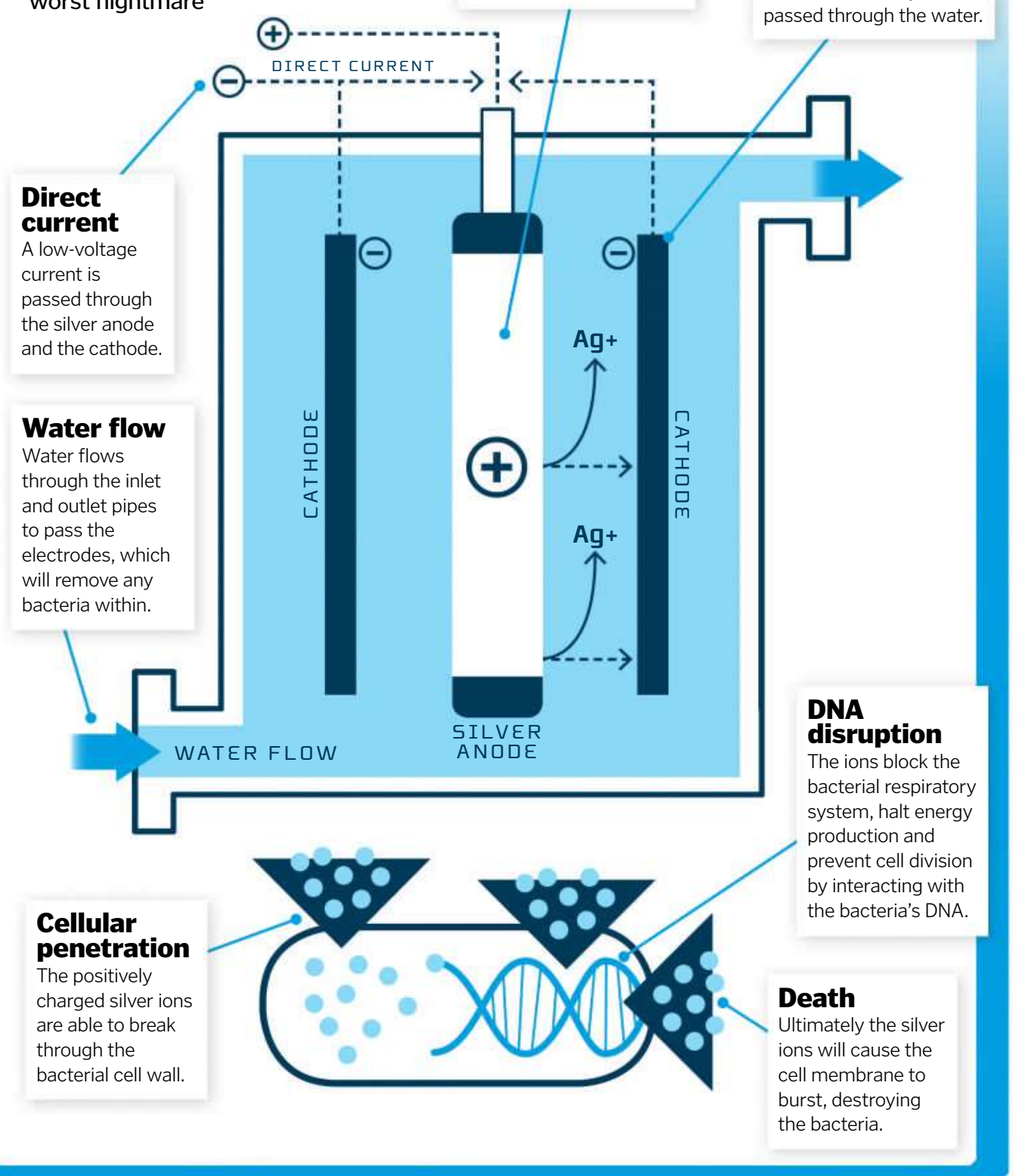
STAYING HYDRATED

Humans have been filtering and cleaning water for thousands of years. However, in the 1960s NASA researchers at Johnson Space Center took purification to the next level. What they created was a pocket-sized purification system that used silver ions to kill bacteria in water.

Silver ions naturally break down the bonds between the DNA and proteins in bacteria, ultimately destroying it. This process is exploited by the water purifier, which electronically releases copper and silver ions in the water to kill the bacteria and other single-celled organisms such as algae, which are then filtered out. The technology has been used to clean not only the water supply in space, but is also a common method on Earth to sterilise drinking water and kill harmful bacteria in pools and fountains.

Bacteria's silver bullet

Why metal ions are bacteria's worst nightmare


Anode
The positively charged silver anode releases silver ions when a current passes through it.
Cathode
The positively charged silver ions attach to the negatively charged cathode after they have passed through the water.
DIRECT CURRENT
Direct current
A low-voltage current is passed through the silver anode and the cathode.
Water flow
Water flows through the inlet and outlet pipes to pass the electrodes, which will remove any bacteria within.
CATHODE
Ag+
Ag+
CATHODE
WATER FLOW
SILVER ANODE
DNA disruption
The ions block the bacterial respiratory system, halt energy production and prevent cell division by interacting with the bacteria's DNA.
Cellular penetration
The positively charged silver ions are able to break through the bacterial cell wall.
Death
Ultimately the silver ions will cause the cell membrane to burst, destroying the bacteria.

BABY FOOD

In exploring how to keep astronauts healthy in space, NASA scientists discovered an ingredient to keep us all healthy from birth. One of the vital omega-3 fatty acids humans need to develop a healthy brain, eyes and heart is called docosahexaenoic acid (DHA), and is predominantly found in a mother's breast milk. However, during the 1980s, scientists at NASA and a company called Martek Biosciences Corporation discovered that a type of algae produced DHA in high quantities. The research that came to this revelation was initially commissioned to explore the potential of algae as a food source for interplanetary travel, but researchers quickly saw the potential for use in baby formula. Currently more than 90 per cent of all infant formula on the market contains added DHA.

Vital nutrients found in baby food were first discovered during NASA's research into microalgae

© Getty

Freeze-dried food can have a shelf life of up to 25 years

© Getty

FREEZE DRYING

Taking food into space comes with a whole host of challenges. How do you store food in space? How do you make food last as long as possible? These are questions that scientists have been asking since before astronauts ventured into the unknown. Freeze-drying was found to be one of the best options. The process of this extreme dehydration wasn't invented by NASA scientists, however. It was the creation of French physician Jacques-Arsène d'Arsonval during World War II. However, it was NASA-funded research in the 1970s which developed it into the widespread preservation method used today.

Freeze-drying allows food to be preserved for longer while maintaining its nutritional value by exposing foods to a series of freezing and drying. First food is frozen solid in a freezing chamber, and then a vacuum pump is used to lower the air pressure within. Along with a little bit of added heat, this combination of the freezing temperature, low air pressure and then heat causes the frozen water content of the food to escape directly as vapour, bypassing its liquid state, known as sublimation. The process takes several hours, and once completely dried out the food is packaged in moisture-free containers to prevent rehydration.

5 FACTS ABOUT MEDICAL SPACE INNOVATIONS

1 Light-emitting diodes (LEDs)
These energy-saving bulbs are used to grow plants on the International Space Station, but also contributed to the creation of medical devices such as the WARP 10, which uses LEDs for muscle treatments.

2 Left ventricular assist device (LVAD)
NASA aerospace engineers helped to design a heart pump called an LVAD. This device helps to keep the heart pumping while a patient awaits a heart transplant.

3 Digital mammography
NASA commissioned the creation of high-tech silicon chips for digital imaging aboard the Hubble Space Telescope Imaging Spectrograph. These went on to be used in mammogram tests to detect breast cancer.

4 Ear thermometers
These thermometers use NASA and Diatek-developed infrared astronomy technology to measure the heat energy emitted from your ear.

5 Artificial limbs
Research into shock absorption materials and robotics for spacewalks have been adopted for dynamic artificial limb creation.

Without NASA's flight impact research, we might not have comfortable running shoes

© Getty

FUNCTIONAL FASHION

It was one small step for man, one giant step for humankind's functional fashion. One of NASA's many technology spin-offs was the revolution of safety suits and footwear around the world. Back in the early 1970s, engineers at Johnson Space Center were asked by the nation's fire chiefs to use their knowledge of astronaut spacesuit life-support systems to give their fire suits an upgrade, which at the time weighed around 14 kilograms. It took NASA four years, but engineers managed to create firefighter outfits that were around one-third of their original weight. Taking these spacesuit adaptations a step further, NASA developed a process called 'blow rubber moulding', inadvertently creating a new wave of athletic shoes. Initially created to make space helmets, the process involves blowing air into heated plastic or rubber to form a hollow mould. In the case of shoe development, this allows hollow soles to be made and filled with shock-absorbing material. It was a concept that athletic shoe manufacturer Nike found attractive. In 1978 the company launched the first-ever Nike Air, which encapsulated dense gases into rubber membranes to create an 'air' bag.

LOOKING INSIDE BODIES

CT (Computed tomography) scanners, are commonly found in hospitals around the world. However, the technology's origins can be traced back to pioneering work at NASA. During the Apollo lunar landing program in the mid-1960s, computer-enhanced digital image processing was created to enhance pictures of the Moon.

This technology paved the way for British engineer Godfrey Hounsfield to create the first CT scanner in 1972. This large piece of medical equipment uses a rotating X-ray source to take cross-section images of the body. A computer can then compile those images together to create a two- or three-dimensional image.

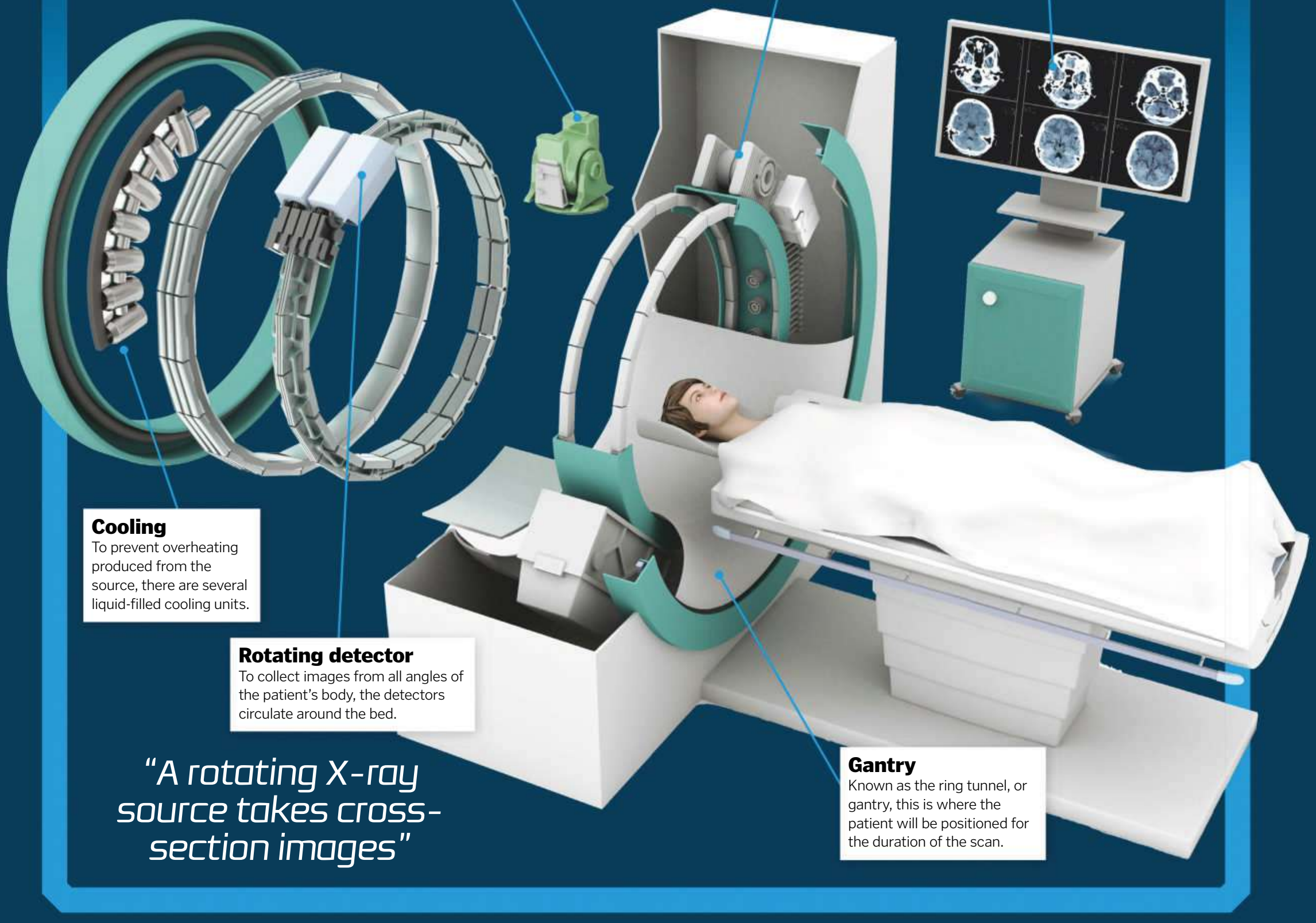
The technology then made its way back to NASA engineers in the late 1980s to allow them to take a look inside rockets. The Advanced Computed Tomography Inspection System (ACTIS) is essentially a giant CT scanner that enables aerospace engineers to spot any defects in the structure of their spacecraft or engines.

© Getty

A CT scanner can be used to diagnose a wide range of injuries and diseases

Inside the scanner

How a CT scanner takes images of our insides



X-ray
X-ray beams are generated from a vacuum X-ray tube. These beams interact differently with different tissue and create contrasting images.

Fan
Fans are used to pump out any warm air from the gantry to keep the machine cool.

Monitor
The accompanying computer assembles the images of slices of the body on an adjacent monitor.

Cooling
To prevent overheating produced from the source, there are several liquid-filled cooling units.

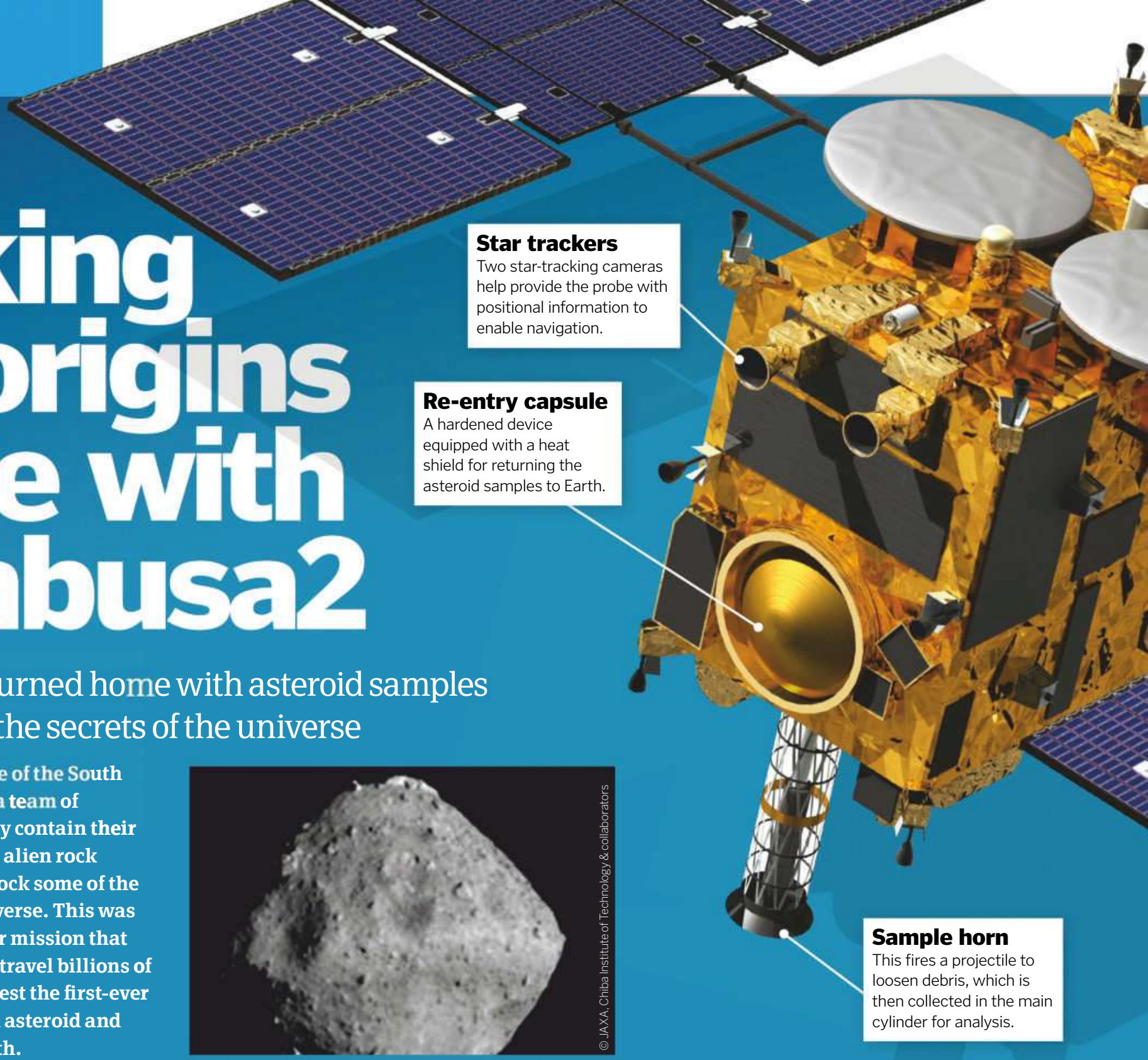
Rotating detector
To collect images from all angles of the patient's body, the detectors circulate around the bed.

Gantry
Known as the ring tunnel, or gantry, this is where the patient will be positioned for the duration of the scan.

"A rotating X-ray source takes cross-section images"

Seeking the origins of life with Hayabusa2

This probe has returned home with asteroid samples that could unlock the secrets of the universe


Star trackers
Two star-tracking cameras help provide the probe with positional information to enable navigation.
Re-entry capsule
A hardened device equipped with a heat shield for returning the asteroid samples to Earth.
Sample horn
This fires a projectile to loosen debris, which is then collected in the main cylinder for analysis.

Under the hot sunshine of the South Australian outback, a team of scientists could barely contain their excitement as they collected alien rock samples that could help unlock some of the biggest mysteries of the universe. This was the culmination of a six-year mission that saw a Japanese space probe travel billions of miles through space to harvest the first-ever subsurface samples from an asteroid and parachute them back to Earth.

Hayabusa2 was launched back in 2014, and has since travelled 3.2 billion miles on a round trip to visit the asteroid Ryugu. The spacecraft arrived in 2018 and touched down twice, where it deployed two rovers and a small lander onto the surface. It also fired a device into the asteroid in February 2019 to create an artificial crater – the first time this has ever been done – allowing the probe to collect an untouched sample from beneath the surface to deliver back to Earth.

© JAXA, Chiba Institute of Technology & collaborators

A camera image of the spinning, diamond-shaped asteroid Ryugu

After spending 18 months at the asteroid the probe then headed home, and in the early hours of 6 December 2020 dropped the 40-centimetre-diameter capsule containing the precious samples it had collected – weighing only 0.1 grams – into the atmosphere 75 miles above Earth.

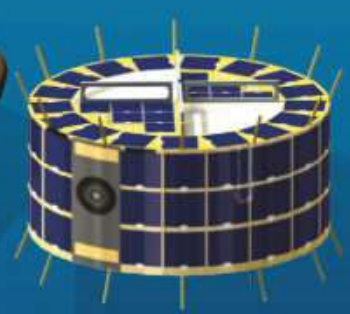
Professor Masaki Fujimoto, from the Japan Aerospace Exploration Agency (JAXA), said the mission could shed light on how life reached our planet: "Originally, Earth didn't have water at all. Something had to bring water to our planet to make it habitable. Something like Ryugu brought water to Earth, and that's why we are here."

With its cargo safely dropped off, Hayabusa2 set off on its next mission. The craft is now heading for another distant asteroid called 1998 KY26, with the mission expected to take about ten years.

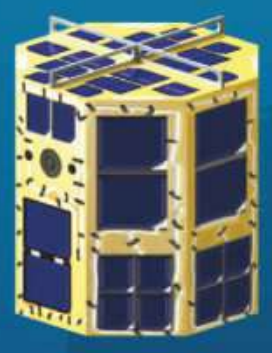
Mothership

The probe features a range of deployable scientific equipment

Re-entry capsule
The capsule which contained the samples was equipped with a heat shield to help it return to Earth.

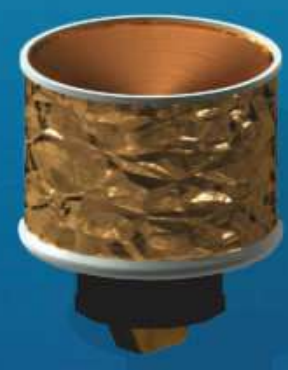


MINERVA-II-1A
One of two MINERVA rover vehicles, standing for Micro-Nano Experimental Robot Vehicle for Asteroid.



MINERVA-II-2
This rover was sent into orbit around Ryugu to take gravitational measurements. It then impacted the asteroid in October 2019.

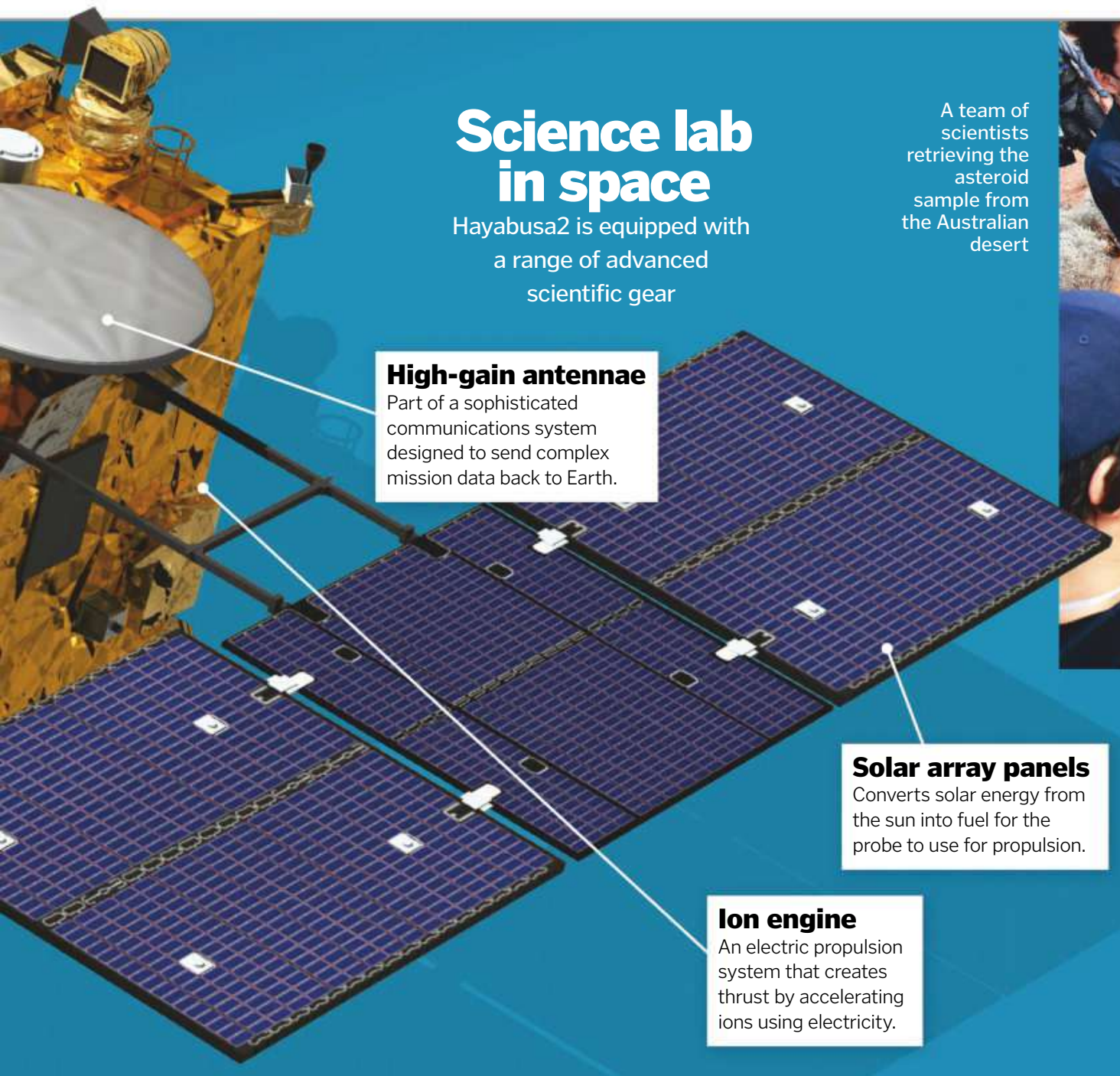
MASCOT lander
Standing for Mobile Asteroid Surface Scout, MASCOT is a 'hopping' lander designed to take pictures and record data.



Impactor
A two-kilogram copper device which was dropped to the surface at high speed to make an artificial crater.

Science lab in space

Hayabusa2 is equipped with a range of advanced scientific gear



High-gain antennae
Part of a sophisticated communications system designed to send complex mission data back to Earth.

Solar array panels
Converts solar energy from the sun into fuel for the probe to use for propulsion.

Ion engine
An electric propulsion system that creates thrust by accelerating ions using electricity.

A team of scientists retrieving the asteroid sample from the Australian desert

Diamond in the sky

Asteroid 162173 Ryugu – to give its proper name – is a diamond-shaped asteroid that was first discovered in 1999 by the Lincoln Near-Earth Asteroid Research (LINEAR) project.

Ryugu means 'dragon palace' in Japanese, which references a magical underwater castle in a Japanese folk tale. In fact, the folk story bears an uncanny resemblance to Hayabusa2's mission. The tale centres on a fisherman who visits the palace and returns with a mysterious box, much like the sample collected.

JAXA estimates the asteroid's size to be about 900 metres in diameter, and it orbits the Sun between Earth and Mars.

Scientists believe it broke off from a larger celestial body a long time ago, and although its surface is thought to be between 8.9 and 158 million years old, some of Ryugu's individual rocks are thought to be up to 4.6 billion years old.

Because it occasionally crosses Earth's orbit, Ryugu is classified as 'potentially hazardous'. As it flies it spins around, rotating every 7.6 hours.

© JAXA, Chiba Institute of Technology & collaborators

"Something like Ryugu brought water to Earth, and that's why we are here"

Down to Earth

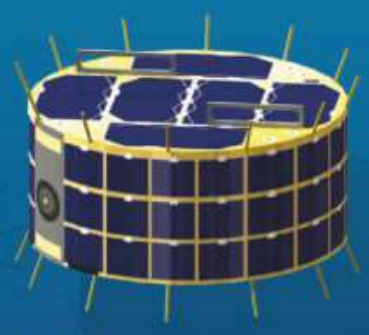
Protected by special heat shields, the capsule containing the samples was dropped back to Earth and looked just like a shooting star as it burned through the atmosphere. Then at about six miles above ground, a parachute opened to slow its fall. It landed safely in the Woomera Prohibited Area of South Australia.

Scientists are excited because the asteroid is thought to be the type that carbonaceous meteorites come from, which could contain amino acids – the building blocks of life. And because some of the samples are from beneath the surface, they will have been untainted by cosmic radiation and other environmental factors.

© JAXA, Chiba Institute of Technology & collaborators

A fireball seen in the Australian sky was the asteroid sample hitting the atmosphere

Target markers
A sort of mini bean bag that's dropped to the surface to form an artificial landmark so the probe knows where to land.



MINERVA-II-1B
The second of two MINERVA rover vehicles. This one contains three rather than four cameras.

NIRS3
An infrared spectrometer that uses rays to investigate mineral and water changes as well as chemical reactions of minerals.

An image of the asteroid's surface taken by one of the probe's mobile rovers

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Secrets of the SYNCHROTRON

Find out how the UK's largest laboratory can accelerate electrons to nearly the speed of light

Electromagnetic (EM) radiation is incredibly useful. It enables us to transmit music wirelessly over large distances, cook food in our microwaves and see the world around us in vivid detail. However, now more than ever, electromagnetic radiation is also crucial in studying the physical, environmental and life sciences that are making real breakthroughs for people on a day-to-day basis. From the creation of new medical drugs and vaccines through to the testing of revolutionary artificial organs and onto discoveries that allow diseases to be prevented, the harnessing of EM radiation on a large scale is truly expanding horizons in the scientific world.

In the UK that revolution is happening at the Diamond Light Source national synchrotron facility in Oxfordshire, a high-tech particle accelerator that excels in generating vast quantities of EM radiation in the form of synchrotron light. **How It Works** decided to take a trip to this cutting-edge science site to see what working there is like on an average day and what groundbreaking experiments are currently being investigated...

Exploring the synchrotron

A good place to start would be to explain what a synchrotron actually is. Essentially it's a large, complex system of machines that generates electrons, accelerates those electrons to near light speed and then deposits them in a large storage ring. The high-energy electrons then fly around the ring circuit continuously until they are manipulated to generate very high-intensity X-ray light; we are talking about electrons with around three gigaelectronvolts (GeV), a GeV being a unit of energy equal to a billion electron volts. This is the light that scientists can utilise in their experiments.

Right now we're about to meet with Dr Guenther Rehm, head of the Diamond synchrotron's beamline diagnostics group. This is the team responsible for ensuring that when visiting scientists need X-ray light, they are able to get it. We step through from Rehm's office in Diamond House, a sleek, glass-walled complex in which the majority of the facility's staff are based. Then, once we're across the security-controlled bridge into the synchrotron facility itself, he begins to describe to us exactly how the system works.

The synchrotron here consists of four main parts, the first of which is an electron gun. Sitting at the heart of the facility, this gun is responsible for generating electrons by heating a high-voltage cathode in a vacuum, then forcing them to bunch up together and compress into compact groups; this is achieved by passing the beam of electrons through a cavity where an alternating electric field is active.

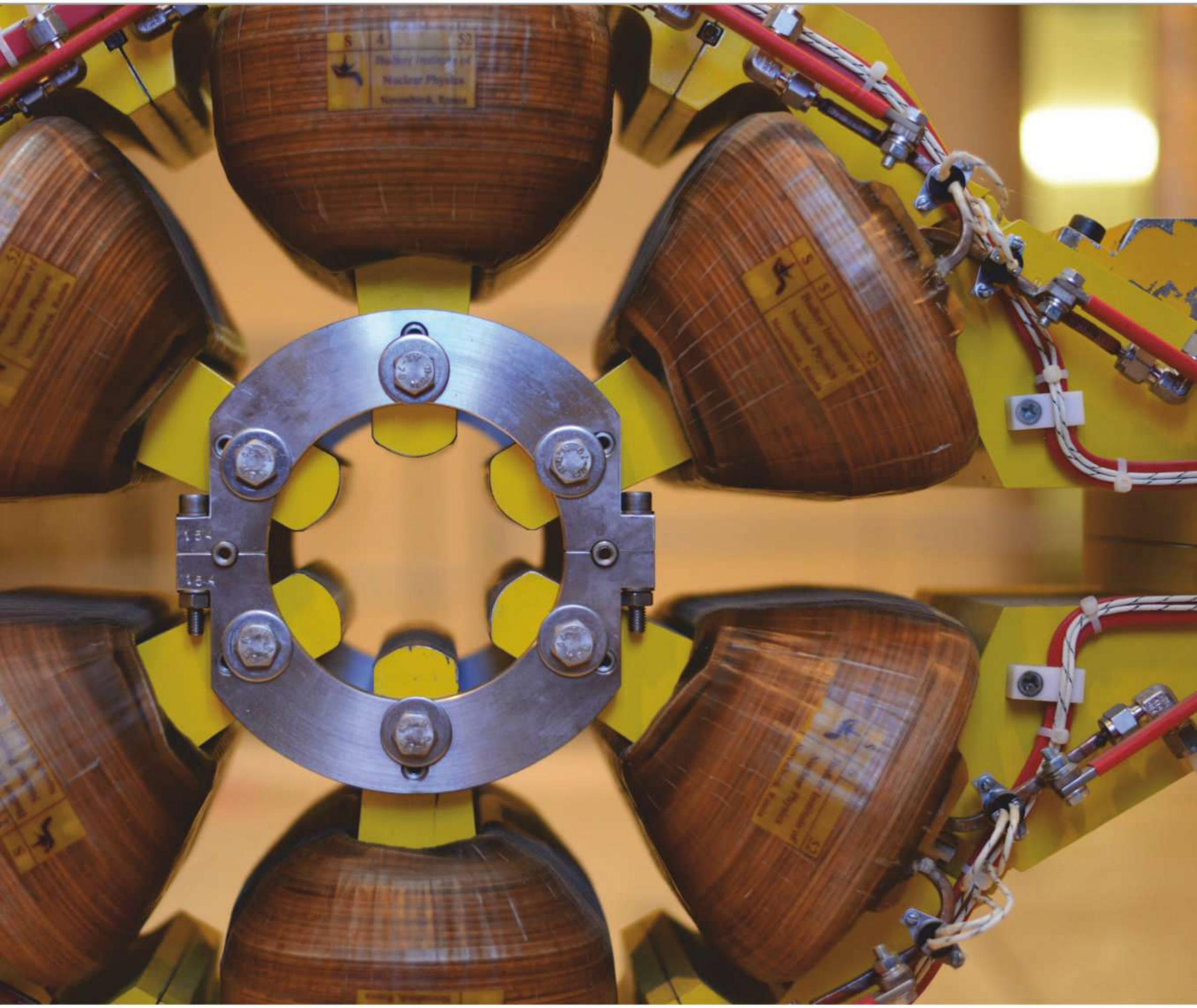
From the bunching cavity, a beam of compressed groups of electrons passes into a linear accelerator. This part of the synchrotron uses a series of electric fields to force the compressed groups of electrons in the stream to accelerate to close to the speed of light and up to a charge level of 100 megaelectronvolts (MeV). From here the sped-up bunches of electrons are injected into the booster synchrotron.

The booster synchrotron sits just off the linear accelerator. It is a 158-metre, O-shaped stainless-steel tube vacuum surrounded by magnets that sits within the synchrotron's storage ring and other facilities. This smaller synchrotron receives the electrons, and then – with the help of 36 dipole magnets – bends them around the vacuum circuit while they are accelerated further up to the necessary extraction energy of three GeV. Travelling at almost the speed of light and carrying an insane energy level, the electron bunches are lastly injected into the synchrotron's storage ring.

The storage ring is similar in both build and purpose to the booster ring, but on a far larger scale. The storage ring consists of a vacuum in which the charged electrons travel, and a series of magnets, including dipole-bending magnets

One of the synchrotron's sextupole magnets. These are responsible for achromatic correction and maintenance of a stable electron orbit within the facility's storage ring

DID YOU KNOW? *Diamond is a medium-energy synchrotron – it currently has 32 beamlines*



The Diamond synchrotron is located near the city of Oxford in the UK. Its advanced technology attracts scientists from all over the world

to manoeuvre the beam around the circuit, quadrupole and sextupole magnets to ensure accurate beam focus and position, as well as special magnets called insertion devices (IDs) to manipulate the electrons for synchrotron light production.

The IDs are the real stars of the synchrotron, capable of forcing passing electrons to oscillate around their straight course. As a result of their resistance, super-powerful X-rays are produced. As such, prior to any beamline – offshoots from the ring where experiments take place – you'll find an ID. The electrons enter the device, oscillate and create X-rays. While the electrons are flung farther down the storage ring by dipole magnets, photons continue straight down the beamline for use in experiments.

Staying in control

Next we arrive at beamline central control. A large, spacious room overlooking approximately a third of the expanding facility, the area is filled with a main bank of monitors and two members of the diagnostics team manning computer systems. Rehm explains that the day-to-day operation of the synchrotron is heavily automated, hence the minimal staffing. However, due to the incredible complexity of the systems involved in creating and maintaining high-energy electron beams, the status of the complex has to be constantly monitored. Indeed, we had expected that controlling an electron beam of such magnitude would be no easy feat.

At all times the beam in the storage ring at the synchrotron is analysed within the control room for charge level, position, time structure and electron losses. This is done through a piece of software referred to as EPICS: Experimental Physics and Industrial Control System. This allows the invisible beam's properties to be visualised via a variety of sensors, monitors and cameras within the ring.

In a demonstration of how this works, Rehm shows how over a ten-minute period the bunched electrons in the storage ring suffer inevitable loss. This is due to collisions and residual gas molecules, as well as energy loss through the generation of synchrotron light by the insertion devices and bending by the dipole magnets. To maintain optimal beam stability and synchrotron light quality, it is automatically topped up periodically. Watching a live graph in EPICS, we see how the overall charge level drops within the ring and then, precisely after ten minutes, returns back to its start level.

Rehm explains that not only is this topping up automatic, but the system can actually target the parts of the beam in which the electrons have been lost from; this makes for an even, stable distribution of energy around the ring for light

Diagnostics centre
The synchrotron's operation is controlled and monitored from a central control room. Despite many systems being automated, the room is permanently staffed in case of a serious error.

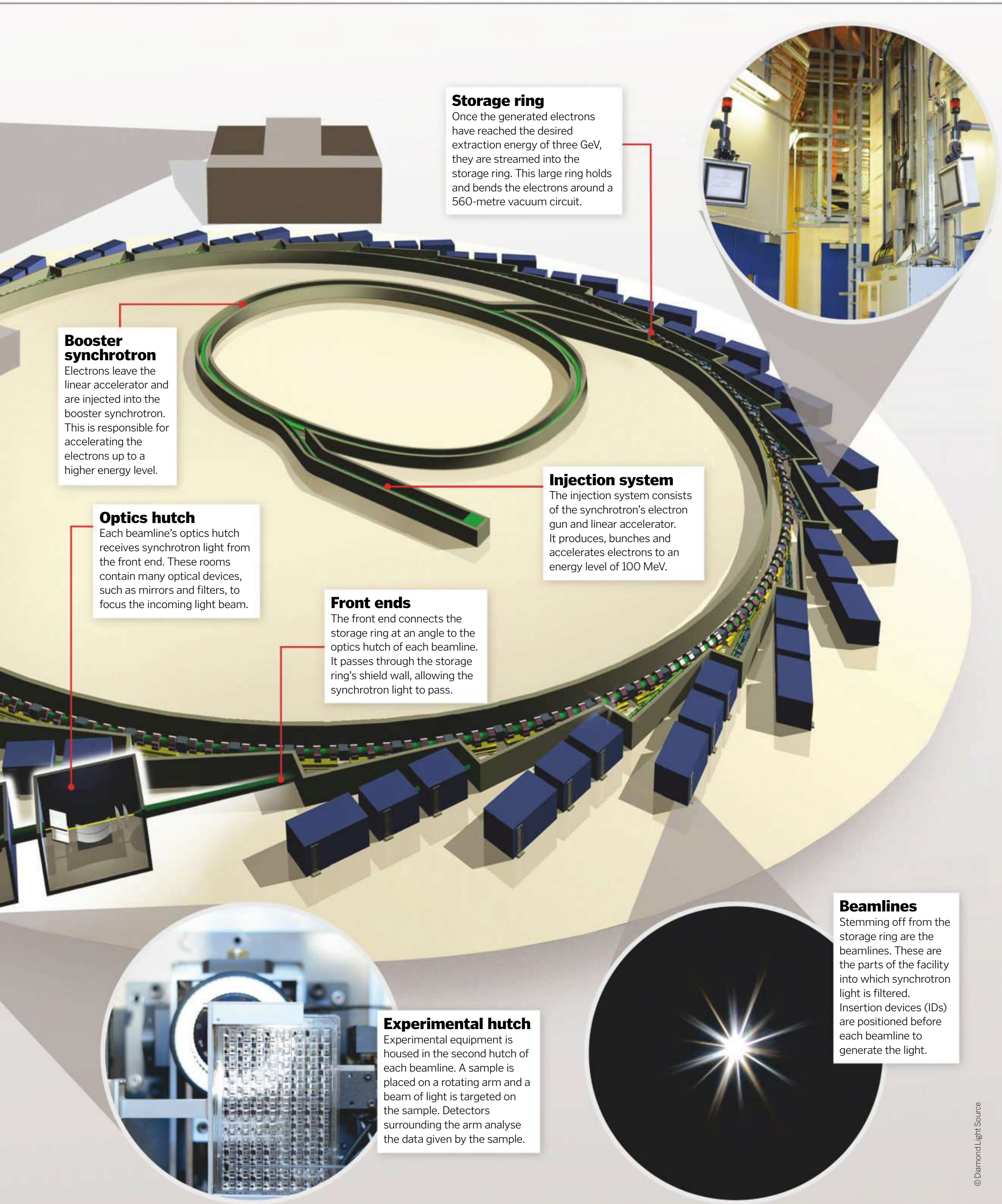
Control cabin
This is the final hutch of each beamline and is where the scientific teams monitor and control their experiments and equipment.

"The IDs are the real stars of the synchrotron, forcing electrons to oscillate around their straight course"

IDs up close

Insertion devices (IDs) are arrays of incredibly strong magnets lined up in two rows – top and bottom – next to each other in tight lines that have very strong magnetic fields. The magnets are arranged to generate a specific pattern of vertical-alternating magnetic field. When electrons pass through it, this causes them to oscillate – vibrate back and forth. This oscillating motion generates synchrotron radiation in the form of photons, which can then be siphoned off for various different experiments in synchrotron facilities.

DID YOU KNOW? *The storage ring is not actually a circle, but a 24-sided polygon*



Storage ring
Once the generated electrons have reached the desired extraction energy of three GeV, they are streamed into the storage ring. This large ring holds and bends the electrons around a 560-metre vacuum circuit.

Booster synchrotron
Electrons leave the linear accelerator and are injected into the booster synchrotron. This is responsible for accelerating the electrons up to a higher energy level.

Injection system
The injection system consists of the synchrotron's electron gun and linear accelerator. It produces, bunches and accelerates electrons to an energy level of 100 MeV.

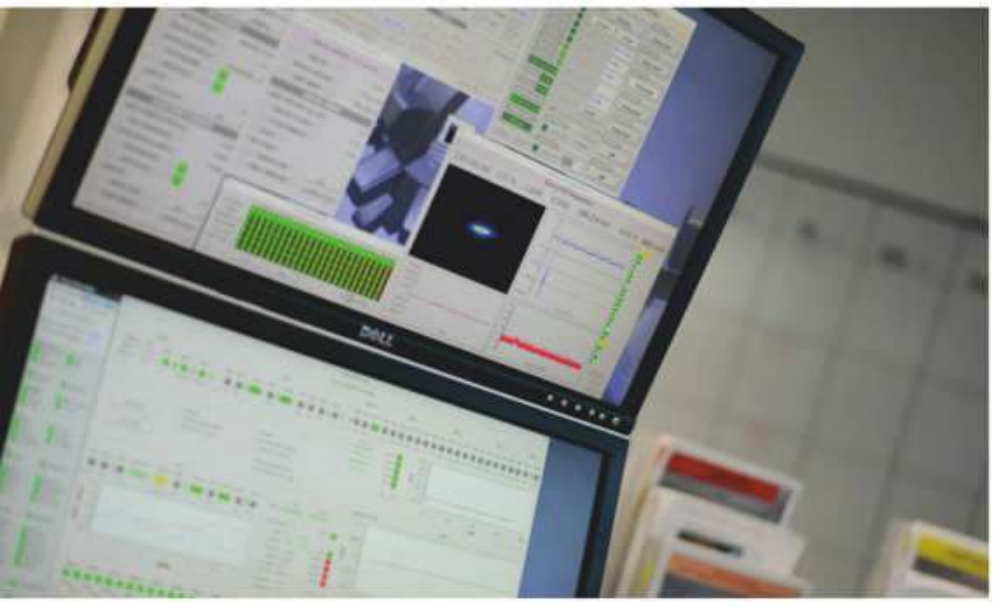
Optics hutch
Each beamline's optics hutch receives synchrotron light from the front end. These rooms contain many optical devices, such as mirrors and filters, to focus the incoming light beam.

Front ends
The front end connects the storage ring at an angle to the optics hutch of each beamline. It passes through the storage ring's shield wall, allowing the synchrotron light to pass.

Experimental hutch
Experimental equipment is housed in the second hutch of each beamline. A sample is placed on a rotating arm and a beam of light is targeted on the sample. Detectors surrounding the arm analyse the data given by the sample.

Beamlines
Stemming off from the storage ring are the beamlines. These are the parts of the facility into which synchrotron light is filtered. Insertion devices (IDs) are positioned before each beamline to generate the light.

© Diamond Light Source



An internal view of the Diamond Light Source facility. The yellow line visible front-centre marks the path of the electron beam within the storage ring

generation at all times. This system is truly amazing, capable of injecting additional electrons into the depleted electron bunches smoothly as they fly around the storage ring at almost light speed.

Looking down the beamline

Moving to the heart of the facility, we enter the cavernous main room of the synchrotron. Standing on an elevated gantry bridge, stretching out to both sides, the curved expanses reveal many of the synchrotron's individual beamlines, branching off from a concrete ring. Rehm explains that this is the facility's storage ring, albeit encased within metre-thick, radiation-blocking concrete shielding. On top of the concrete ring is a yellow line – this identifies the actual path of the electron beam inside. According to our guide, a person could lie on top of the concrete for an entire year and only receive a radiation increase of approximately 50 per cent over that from standard background radiation. Simply put, very little radiation escapes the ring.

As we progress to get a better look at the storage ring and beamlines, Rehm begins to tell us about a major challenge of his occupation: consistency of run time.

Despite the synchrotron having a day's downtime every week for maintenance, trying to keep all the various systems and subsystems working together continuously without failure is challenging. Scientists are visiting the facility all the time, spending months applying and waiting for their chance to use a beamline, so any unscheduled downtime is keenly felt.

It is some of those scientists that **How It Works** is about to meet, but first Rehm has one more stop. Sandwiched between two beamlines is a small, black room. On entering, we find a large table stuffed with machines, pipes, optics and cabling. Behind this, a small hole is cut in the wall. This is the optics diagnostics cabin, and it allows the support scientists to explore the temporal structure of the stored electron beam, revealing its fill pattern – how much charge is in each of the electron bunches. Rehm holds his hand in front of the incoming beam of light to reveal its apparent weakness, like a faint splodge. We then look down the incoming beam and are immediately dazzled by a piercing bright light. This is but a minuscule replica of the high-energy synchrotron light in the beamlines.

Handling the light

Knowing how the synchrotron works is one thing, but what does it actually mean for the world at large? Enter Professor Nick Terrill, the principal beamline scientist for the small angle scattering and diffraction beamline (I22). Among many other examples, Terrill describes how a team recently used I22 to test new polymer-material artificial heart valves. The team built a tiny device to stretch the valve to reproduce the effects of a heartbeat and then used the synchrotron's high-energy X-ray light source to image the internal structure of the polymer valve in continuous resolution over a long period. These sorts of polymer valves will soon be a common replacement for problematic mechanical and animal implant valves.

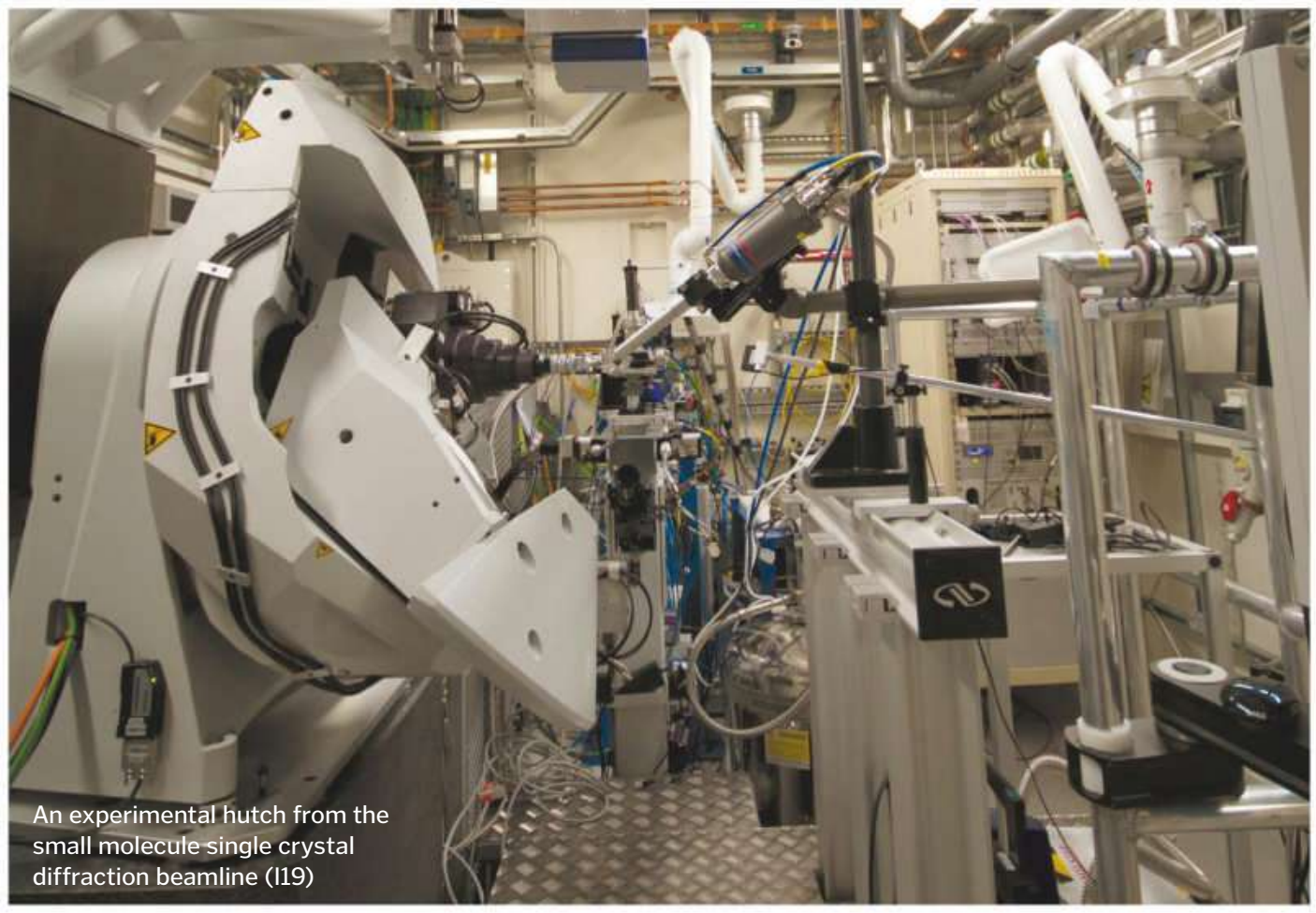
After a short walk around the synchrotron's outer walkway to beamline I24, we come across the microfocus macromolecular crystallography station. I24 is staffed by Diamond's senior support scientist Dr Danny Axford, who explains how the team is working on membrane proteins, exploring their structures – something of vital importance in the creation of new drugs, among other applications. This project is a collaboration between Imperial College London and Diamond itself. It is making use of both the on-site Membrane Protein Lab, which negates the need to transport samples and potentially damage them, as well as a new technique in which a wide variety of crystal samples can be imaged in a short space of time.

After allowing the visiting scientists to finish analysing their current batch of samples, Axford

opens up I24's experiment's hutch – the room containing the liquid-nitrogen storage tanks, imaging sensor, robotic arm, synchrotron light-focus optic and sample array all needed to perform experiments. The sensor in this room is state-of-the-art, and alongside the sample-holding array allows rows of crystals to be imaged at room temperature. This is incredibly useful, as heat from the imaging process damages crystals, so capturing their structure quickly is crucial – hence why many samples are cryogenically cooled.

Our next port of call is the small molecule single crystal diffraction beamline (I19), where we see how a variety of crystallised samples are being analysed through diffraction techniques, with samples ranging in areas from cancer to hydrogen storage. Next door in I20, we get a detailed tour of the impressive, versatile X-ray absorption spectroscopy beamline by principal beamline scientist Dr Sofia Diaz-Moreno.

This beamline, which is much larger than any of the others, has two experiment hutches that share the line to enable different types of spectroscopy analysis. What really excites us is hearing about how important chemical components in catalysts – even in very low concentrations – can have their structure illuminated and imaged continuously. This ability to image reaction processes at an atomic level and at microsecond time scales is truly mind-blowing, and is allowing scientists to understand things such as catalysts, metalloproteins – metal ion-containing proteins – and toxic materials like never before.



An experimental hutch from the small molecule single crystal diffraction beamline (I19)

Racing the electron beam

After witnessing first-hand just how this impressive facility is enabling scientists to make radical breakthroughs in many fields of science, we have time for one final stop: a stroll on the roof of the storage ring. Ascending back up to the first floor from beamline level and crossing the metal gantry towards the centre of the facility, we break off and step directly on top of the concrete roof of the storage ring before following the yellow beamline marker around the facility. It takes us close to ten minutes to make a full circuit around the ring; by way of comparison, it takes the hyper-charged electrons beneath our feet just two-millionths of a second.

> *"The ability to image reaction processes at atomic levels and microsecond time scales is mind-blowing"*

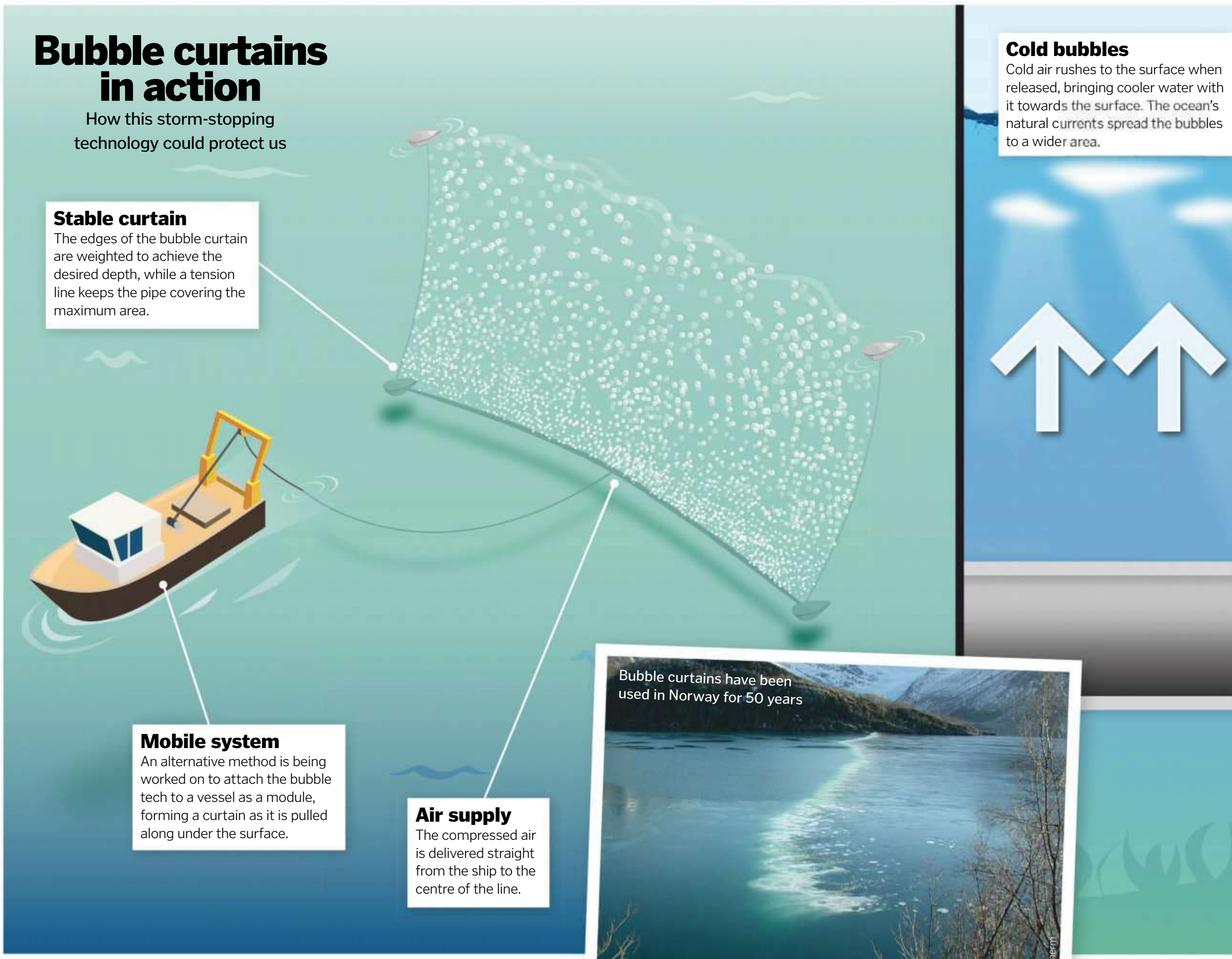
How to stop a hurricane

Could this simple bubble technology reduce the destruction wreaked by these deadly natural disasters?

The most recent hurricane season saw a brutal increase in both the strength and number of hurricanes emerging from the North Atlantic. Scientists have concluded that many more of these tropical storms are tearing apart homes and lives as they surge through towns because of the planet's ever-warming conditions. We can all make changes in an attempt to reduce the long-term effects of climate change, but can any immediate action be taken to improve the situation between these killer hurricane seasons?

OceanTherm is one company dedicated to answering this question. Because hurricanes feed off the heat from the ocean's surface, one potential method that aims to calm these tropical storms – or even stop them in their tracks – is to cool the sea using bubble curtains. Bubble curtains are perforated pipes that stretch across the seas, below the surface. As the bubbles released from the pipe travel upwards to the surface, they bring the cooler water up from the deep to lower the temperature of the water at the surface. This technology isn't new, but its application in preventing tropical storms is. Currently, bubble curtains are used in Norway to produce the opposite effect – increasing the surface temperature. As the country's freezing winters often lead to ice forming on the fjords, water hidden from the air's chill is brought up from the depths to prevent it from freezing.

"The bubbles from the pipe travel upwards to the surface"


Bubble curtains in action
How this storm-stopping technology could protect us
Stable curtain
The edges of the bubble curtain are weighted to achieve the desired depth, while a tension line keeps the pipe covering the maximum area.
Cold bubbles
Cold air rushes to the surface when released, bringing cooler water with it towards the surface. The ocean's natural currents spread the bubbles to a wider area.
Mobile system
An alternative method is being worked on to attach the bubble tech to a vessel as a module, forming a curtain as it is pulled along under the surface.
Air supply
The compressed air is delivered straight from the ship to the centre of the line.
Bubble curtains have been used in Norway for 50 years
© OceanTherm

At temperatures below 26 degrees Celsius, hurricanes can't form and begin to weaken

© Getty

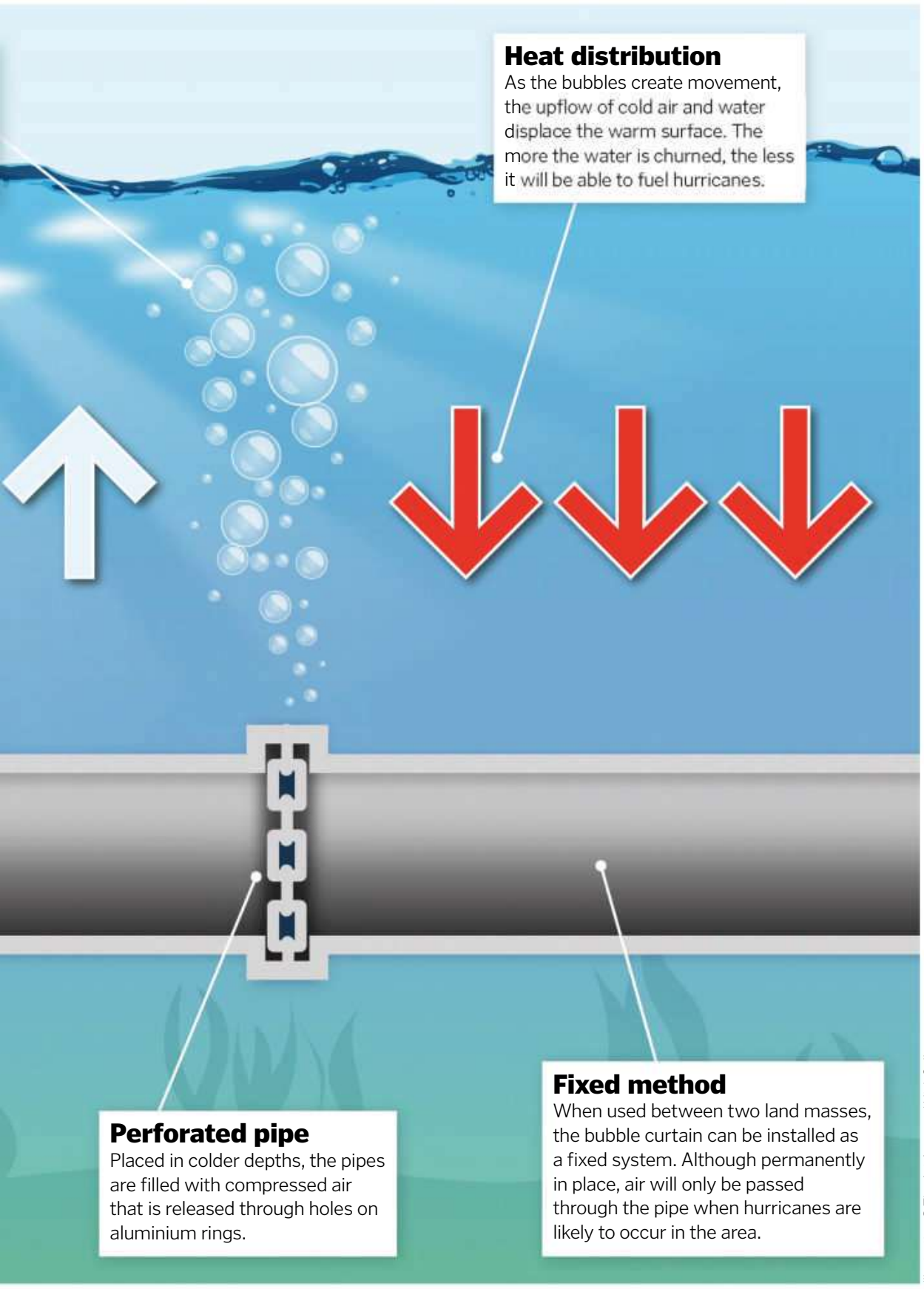

Heat distribution
As the bubbles create movement, the upflow of cold air and water displace the warm surface. The more the water is churned, the less it will be able to fuel hurricanes.
Perforated pipe
Placed in colder depths, the pipes are filled with compressed air that is released through holes on aluminium rings.
Fixed method
When used between two land masses, the bubble curtain can be installed as a fixed system. Although permanently in place, air will only be passed through the pipe when hurricanes are likely to occur in the area.

Illustration © The Art Agency / Nick Sellers

Q&A

Oceantherm CEO

© OceanTherm

Olav Hollingsaeter gained a master's in computer science at the University of Bergen and served in the Norwegian Navy before developing his hurricane-halting concept from the existing bubble curtain technology.

When did you come up with the idea to use this technology for hurricanes?
Seeing the devastating damage caused by Hurricane Katrina in 2005 motivated me. With 1,833 lives lost and enormous damage, we all asked ourselves: 'How did this hurricane become so strong?' The warm surface water was feeding the hurricane with energy, making it stronger. As an old submariner, I knew that the temperatures are colder deeper in the ocean column. I started to think about how to lift this cold water.

How much impact could this have on global storms?
Since hurricanes refuel their energy from the warm ocean surface and get an energy cut-off when the sea surface temperature is below 26.5 degrees Celsius, we feel confident that a colder surface layer could prevent tropical storms and hurricanes from increasing in strength – potentially also reducing their strength. This will have a considerable effect on their devastating impact.

How sustainable is use of the bubble curtain worldwide?
There is a significant climate footprint related to rebuilding after devastating hurricanes, and the flooding and rainfall that come as a result of these devastating storms bring significant pollution back out to the ocean. Preventing this will considerably benefit the climate in addition to saving lives and property. Studies need to assess the effect on the climate and surrounding ecosystems, but we don't anticipate any negative consequences since the cooling is only temporary and very local. The climate footprint of the bubble curtain will be mostly related to the building of the systems and the use of energy when operating the system, which will only be when a tropical storm or a hurricane is coming into an area.

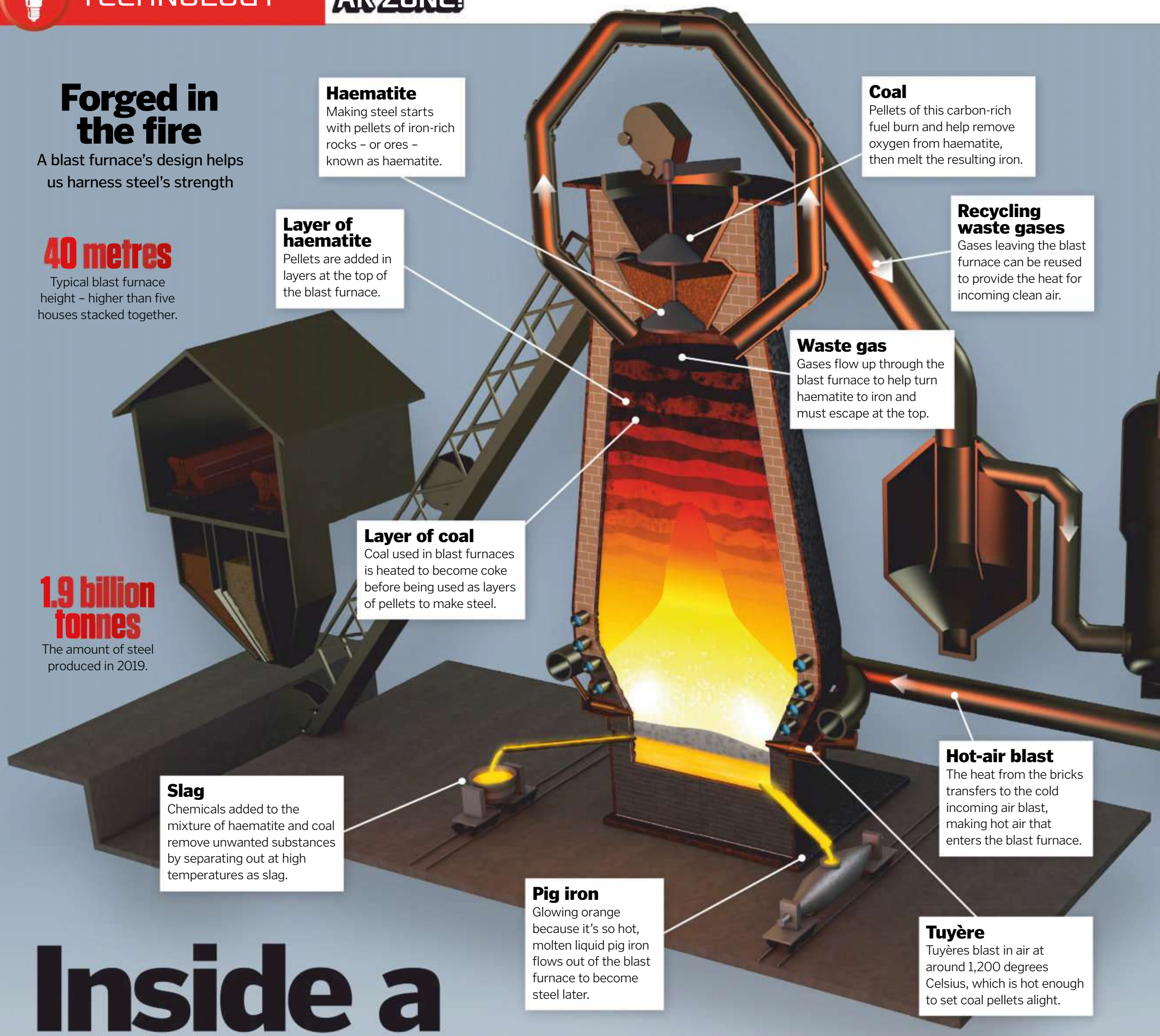
What will make this technology most effective?
The installation will be rather large, including a submerged and moored bubble tube at about 100 metres below the sea surface. To our knowledge, the bubble curtain has never been applied at these depths and in the scale that is necessary for hurricane prevention. Ocean currents will be the true engine in the system, making sure the cooling effect spreads to a larger area. This is necessary in order to have an effect, and really the key to our technology. We help nature to help us. We help nature, by lowering the sea surface temperature, to help us by spreading out the effect with the help of ocean currents.

Forged in the fire

A blast furnace's design helps us harness steel's strength

40 metres
Typical blast furnace height – higher than five houses stacked together.

1.9 billion tonnes
The amount of steel produced in 2019.


Haematite
Making steel starts with pellets of iron-rich rocks – or ores – known as haematite.
Coal
Pellets of this carbon-rich fuel burn and help remove oxygen from haematite, then melt the resulting iron.
Layer of haematite
Pellets are added in layers at the top of the blast furnace.
Recycling waste gases
Gases leaving the blast furnace can be reused to provide the heat for incoming clean air.
Waste gas
Gases flow up through the blast furnace to help turn haematite to iron and must escape at the top.
Layer of coal
Coal used in blast furnaces is heated to become coke before being used as layers of pellets to make steel.
Slag
Chemicals added to the mixture of haematite and coal remove unwanted substances by separating out at high temperatures as slag.
Hot-air blast
The heat from the bricks transfers to the cold incoming air blast, making hot air that enters the blast furnace.
Pig iron
Glowing orange because it's so hot, molten liquid pig iron flows out of the blast furnace to become steel later.
Tuyère
Tuyères blast in air at around 1,200 degrees Celsius, which is hot enough to set coal pellets alight.

Inside a blast furnace

The steel that shapes our modern cities starts from glowing metal made in these massive furnaces

How do the large buildings we see around the modern world stay up? They have skeletons of steel that are strong enough to help support other heavy materials like concrete. That's why steel is one of the world's most important products – and so the blast furnaces that make it are very important too. Blast furnaces make very hot, liquid pig iron. In 2016 up to 900 blast furnaces made and melted over a billion tonnes of this iron, which soon became steel, worldwide. Each one makes up to 12,000 tonnes of molten pig iron per day, running around 19 days out of 20. A few extra chemical steps make pig iron into steel.

Blast furnaces look a bit like tall vases. Conveyor belts pour mixtures of small rocky pellets of haematite, rich in iron but also oxygen, and carbon-rich coal and other ingredients in the top. To make steel, we need to separate the iron from the oxygen. To do this, extremely powerful heaters blow hot air into the bottom of the furnaces hard enough that it flows upwards through the rocks. This air is hot enough to set the coal alight, and the flame's temperature can be above 2,000 degrees Celsius.

This eventually helps bring this mixture above 1,500 degrees Celsius, mixing ingredients together. Some of the carbon from the coal reacts with oxygen, flowing away as carbon monoxide and carbon dioxide gas. The glowing-orange molten pig iron that remains contains a little

Cleaning up waste gases
Before they can release waste gas, the furnace operators remove unwanted components like dust.

One centimetre
The size of haematite pellets used in blast furnaces.

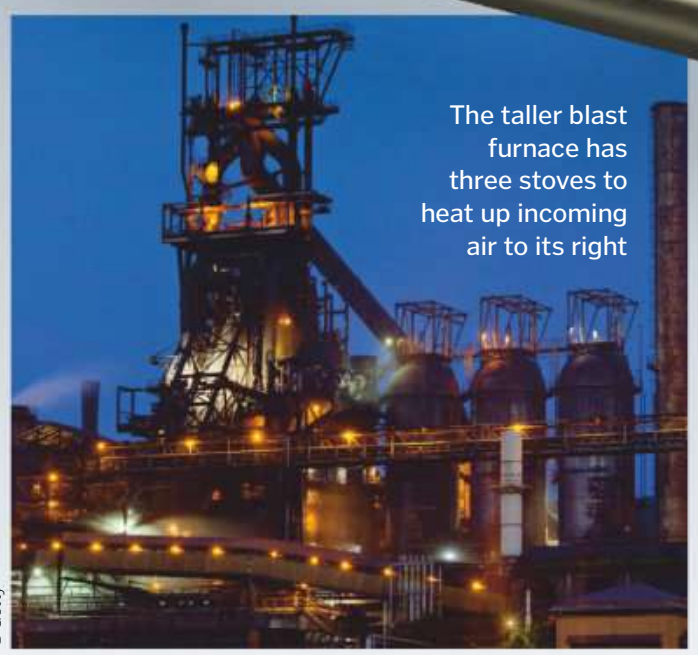
AR ZONE! SCAN HERE

Heating up stoves
Burning the cleaned waste gases heats up stacks of brick inside tube-shaped stoves near the blast furnace.

£450 million
Cost of a furnace making 4 million tonnes of steel annually.

Stoves heat up air
Once the bricks inside the stoves have heated up, they can heat up blasts of incoming cold air.

Illustration © Adrian Mann



The taller blast furnace has three stoves to heat up incoming air to its right

© Getty

25 minutes
The time it takes for 300 tonnes of liquid iron to be converted into steel at Scunthorpe.

carbon, and unwanted elements like sulphur and manganese. Steelworks quickly send this hot metal to mix with other rocks to remove the unwanted elements. They can then add other elements that make the steel stronger, and pour it into moulds. If you aren't careful, this can be a dangerous process – but that's what is needed to harness steel's valuable strength.

© Getty

As rocky pellets fall into a blast furnace, hot air from below sets them alight

© Getty

Pipes circulate gas around blast furnaces to help produce molten iron

Cleaning up coal

Iron and steelmaking has a history going back at least 2,000 years. Blast furnaces became common in Europe in the 1400s, relying on wood to make iron. Partially burning wood made carbon-rich charcoal, which could help remove oxygen from iron-rich rocks. But by the 1700s wood was getting more expensive, as many trees had already been chopped down.

Rocky coal is also mostly carbon, and was cheap and easy to get. But it also contains lots of sulphur, which makes iron brittle. In 1709, an Englishman called Abraham Darby tried using coal that had been heated in a kiln without any air to remove the sulphur, making a product called coke. That change meant that making pig iron was easier, and played a big part in the Industrial Revolution. It later helped a historic cast-iron bridge to be built over the River Severn, in a village now named Ironbridge.

© Getty

Ironbridge in Shropshire, England, was made possible by using coke in blast furnaces

How do stenographers type so quickly?

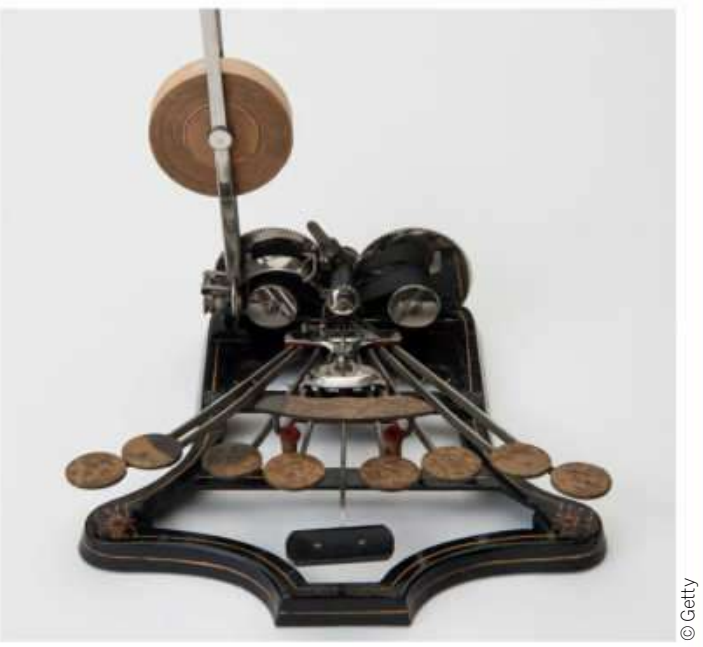
Phonetic word processors let them record court proceedings in real time

If you've ever seen a court drama, you may have heard a prosecutor tell a witness to answer questions truthfully 'for the record'. You may have also heard a lawyer loudly object, declaring something should be 'stricken from the record.' While real-life court cases aren't always this theatrical, the record is very real.

Court cases are documented in detail so that anyone can find out how a judge reached a legal decision. If there's evidence that anything was wrong with the way a case was handled, judgements can be overturned, so it's very important that the official records are accurate.

It falls to the stenographer – sometimes called a court reporter – to write down everything the judge, lawyers and witnesses say during a trial. But the average person speaks between 100 and 130 words per minute. Trying to faithfully write what one person says as they say it at these speeds is practically impossible.

But stenographers have a secret weapon. While a regular computer keyboard has over 100 buttons, their 'stenotype' or 'steno machine' word processors have only 22. Some letters are missing and there are no punctuation keys. But by pressing combinations of buttons – known as a chord – they can produce whole syllables, words or phrases in one movement. This allows them to type at around 200 words per minute and even record multiple people's speech at once. Some can type even faster than that: the Guinness World Record holder Mark Kislingbury reached a jaw-dropping 360 words per minute!



© Getty

The first steno machines appeared in the 19th century. This model is from around 1882

A court reporter at work in 1935

© Getty

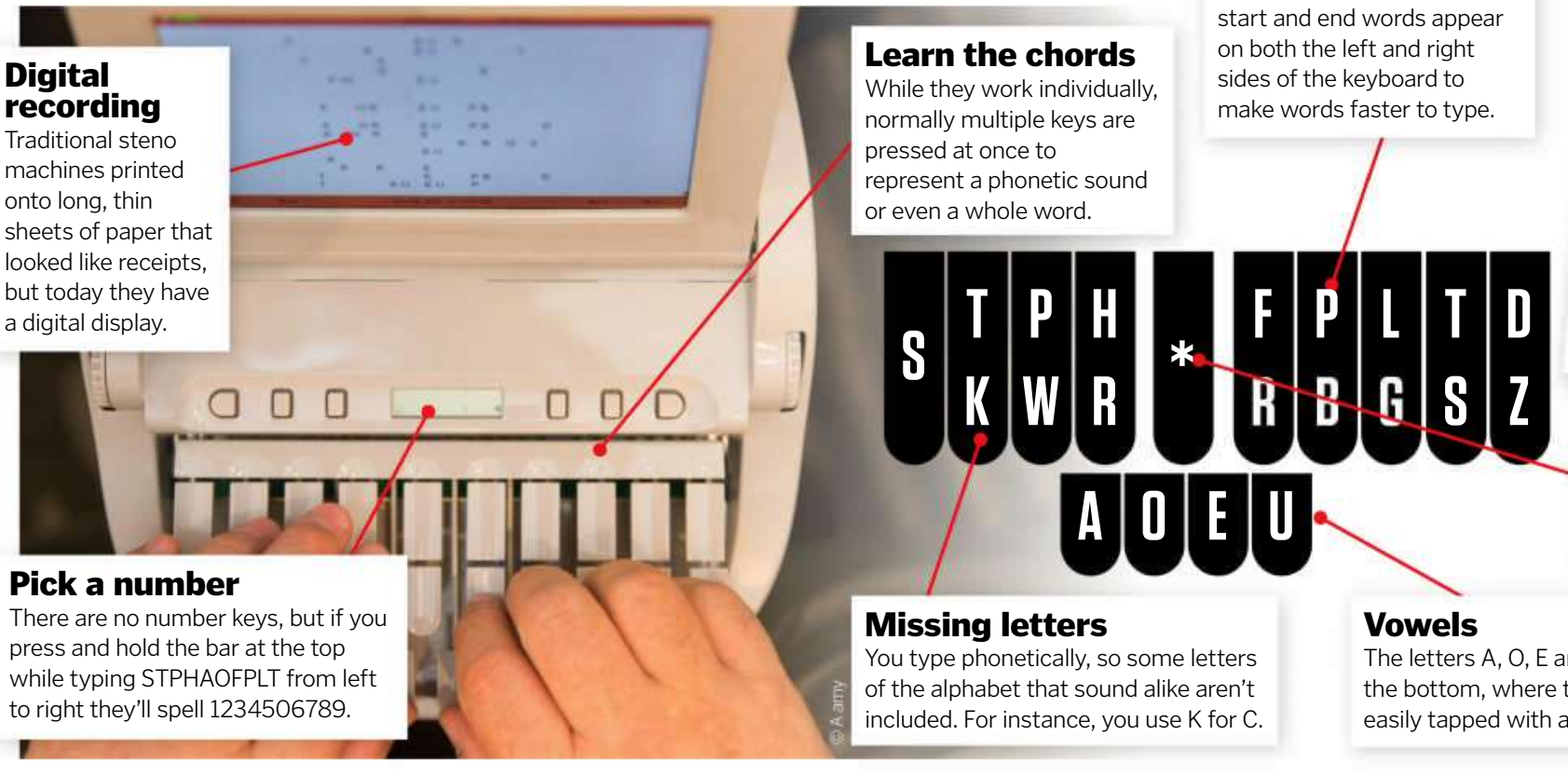
The end of an era?

Throughout history, there has always been someone documenting court cases. Before stenographers there were shorthand writers. They used a complicated code of squiggles to jot down quotes at around 100 words per minute. Even in medieval England, notes were made in abbreviated Latin before being written up in full for the plea rolls.

But this is changing. Since 2012, the Old Bailey and other crown courts in England and Wales have replaced stenographers with the Digital Audio Recording Transcription and Storage System (DARTS). As the name suggests, this involves recording what's said in court with microphones, then transcribing it later. Many other courts around the world are following suit.

Built for speed

The steno machine makes it easy to type more in a single motion



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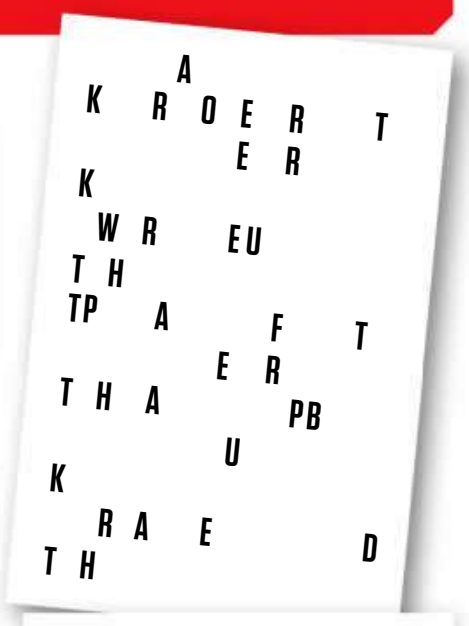
Digital recording
Traditional steno machines printed onto long, thin sheets of paper that looked like receipts, but today they have a digital display.

Learn the chords
While they work individually, normally multiple keys are pressed at once to represent a phonetic sound or even a whole word.

Repeated keys
Letters that both commonly start and end words appear on both the left and right sides of the keyboard to make words faster to type.



Strike the record
The asterisk key can work like a delete button, removing the previous chord. It's typically tapped using the right-hand index finger.

Pick a number
There are no number keys, but if you press and hold the bar at the top while typing STPHAOFPLT from left to right they'll spell 1234506789.

Missing letters
You type phonetically, so some letters of the alphabet that sound alike aren't included. For instance, you use K for C.

Vowels
The letters A, O, E and U run across the bottom, where they can be easily tapped with a thumb.

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OFFER EXPIRES 30 Apr 2021

Cells: the body's building blocks

Trillions of cells keep us alive, but what processes take place within these intricate systems?

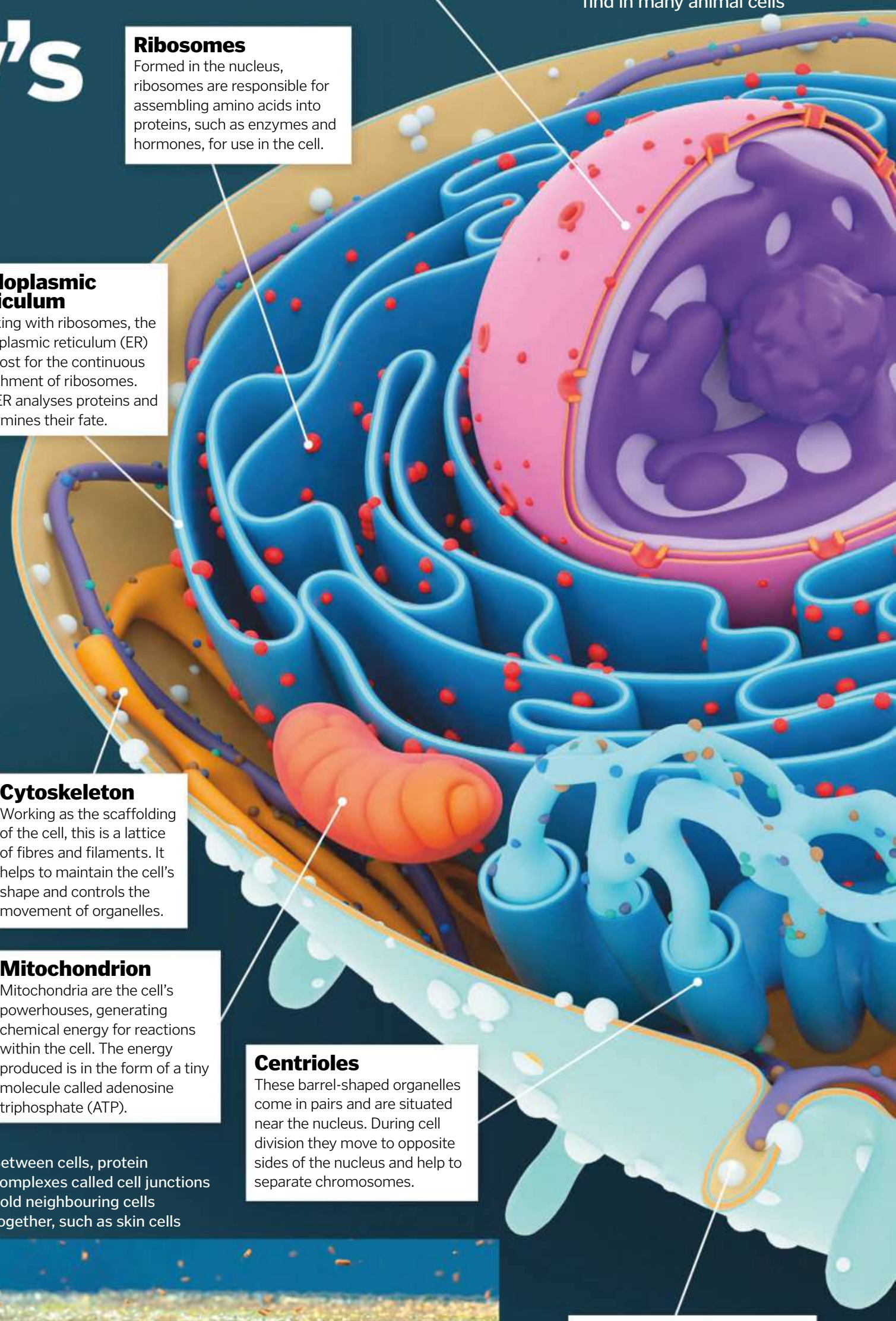
When you look in the mirror, you see a single organism. But on a microscopic level we are packed with over 37 trillion individual units: cells. They play an important and specific role to keep your body operating while performing functions to keep themselves healthy. If you've ever wondered why the human mind and body are so complex, it's down to these many tiny living components that dictate your life. Not only are cells alive, they define what makes an organism a living thing.

Inside all of us, our cells are constantly at work. Each one is carrying out thousands of routine jobs at any given time, and its diverse organelles – organs for cells – have evolved to carry these out efficiently. While human cells have a common structure, there are over 200 major types, each with a specialised structure and function.

Understanding cells means understanding ourselves. They are called the building blocks of life because they are the smallest unit that makes up every system in our body. Individual cells have to perform a certain function. For example, muscle cells need to contract. They are grouped together with matching cells to form a tissue type. Cells in muscle tissues work with the same goal, producing a greater force when their contractions are synchronised. When this tissue connects with other tissue types – like the nerve cells that coordinate the muscles – these multifunctional systems create the complexities that make us human. Each system is reliant on another to carry out their vital roles, and these are made possible by the capabilities of our individual cells.

Cell anatomy

These are the organelles you'll find in many animal cells



Nucleus and nucleolus
The central nucleus holds genetic information and regulates the cell's growth and metabolism. A smaller structure inside called the nucleolus produces ribosomes to be transported outside the nucleus.

Ribosomes
Formed in the nucleus, ribosomes are responsible for assembling amino acids into proteins, such as enzymes and hormones, for use in the cell.

Endoplasmic reticulum
Working with ribosomes, the endoplasmic reticulum (ER) is a host for the continuous attachment of ribosomes. The ER analyses proteins and determines their fate.

Cytoskeleton
Working as the scaffolding of the cell, this is a lattice of fibres and filaments. It helps to maintain the cell's shape and controls the movement of organelles.

Mitochondrion
Mitochondria are the cell's powerhouses, generating chemical energy for reactions within the cell. The energy produced is in the form of a tiny molecule called adenosine triphosphate (ATP).

Centrioles
These barrel-shaped organelles come in pairs and are situated near the nucleus. During cell division they move to opposite sides of the nucleus and help to separate chromosomes.

Vesicle
These organelles aid transport within and out of the cell. Secretory vesicles fuse with the membrane to remove the contents in a process called exocytosis.

Between cells, protein complexes called cell junctions hold neighbouring cells together, such as skin cells

© Getty

Golgi complex

The Golgi complex transports molecules from the endoplasmic reticulum to their required destination. It can also modify these molecules to a specialised function.

Longest living

Because most cells are replaced as you age, much of your body is actually younger than you are. Brain cells are an exception. Most of the neurons in the brain have remained since you were conceived. They don't divide like other cells, and in the case of humans will only die because of disease, injury or because the rest of the body has died. Scientists have proved that brain cells can continue living in a healthy environment by taking them from mice and implanting them into rats. These brain cells continued to live in their new host for twice as long as the original mouse lived.

Microvilli

This part of the cell membrane not only protects the cell's contents, but also increases the surface area so more nutrients can be absorbed into it and toxic substances pushed out.

Lysosome

This small, acidic organelle needs to maintain a low pH level to hold digestive enzymes. These enzymes are sent to digest molecules and make their nutrients available for the cell, while removing any waste products.

© Alamy

Mitochondria have a smooth outer membrane and a folded inner membrane, which can be seen in this electron micrograph image

© CNRI/ Science Photo Library

How superconductors work so efficiently

Superconductors may seem like perfectly ordinary materials, but turn down the temperature and their superpowers are revealed

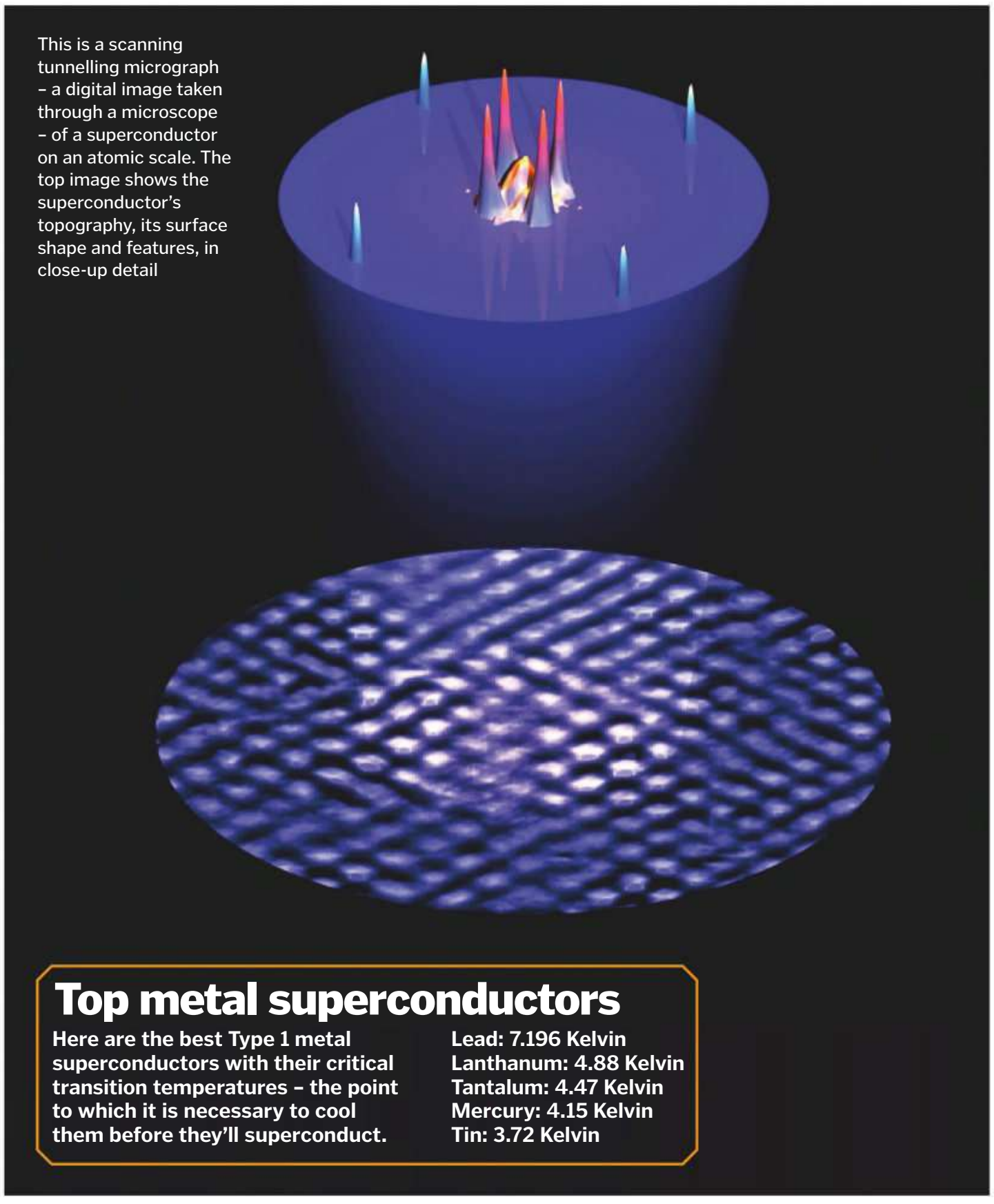
Superconductors are metals – such as lead – or oxides which conduct electricity with no resistance. There's just one catch – to display their superpowers, they need to be kept at a frosty -265 degrees Celsius, or thereabouts.

Peer inside a chunk of lead and you'll see row upon row of neatly packed ions, bathed in a swarm of electrons. These loose electrons are what conduct electricity – set them into motion and you have an electrical current. At room temperature the lead ions vibrate away frenetically. From an electron's perspective, it's like trying to move across a crowded dance floor without spilling your drink. Constant collisions between electrons and ions convert electrical energy into heat – this is resistance.

Turn the temperature down a few hundred notches, however, and the ion vibrations subside, creating a stable lattice. Now as electrons flow through, a new effect comes into play: distortions in the lattice force them into pairs.

These unlikely unions trigger a weird quantum physics quirk: electron pairs throughout the material coalesce into a perfectly synchronised cloud, moving a bit like a school of fish. This means that the swarm of electrons can move through the lattice with no collisions, resulting in no resistance whatsoever.

Thanks to this astounding property, a huge current can be run through a superconductor without it overheating. This means that they can create incomparably powerful electromagnets. These are currently used in MRI scanners, supercomputers, particle accelerators like the Large Hadron Collider and levitating maglev trains.



This is a scanning tunnelling micrograph – a digital image taken through a microscope – of a superconductor on an atomic scale. The top image shows the superconductor's topography, its surface shape and features, in close-up detail

Top metal superconductors

Here are the best Type 1 metal superconductors with their critical transition temperatures – the point to which it is necessary to cool them before they'll superconduct.

Lead: 7.196 Kelvin
Lanthanum: 4.88 Kelvin
Tantalum: 4.47 Kelvin
Mercury: 4.15 Kelvin
Tin: 3.72 Kelvin

Superconductor evolution

How It Works takes a journey through the last century to see just how far superconductors have come

1911
Absolute zero

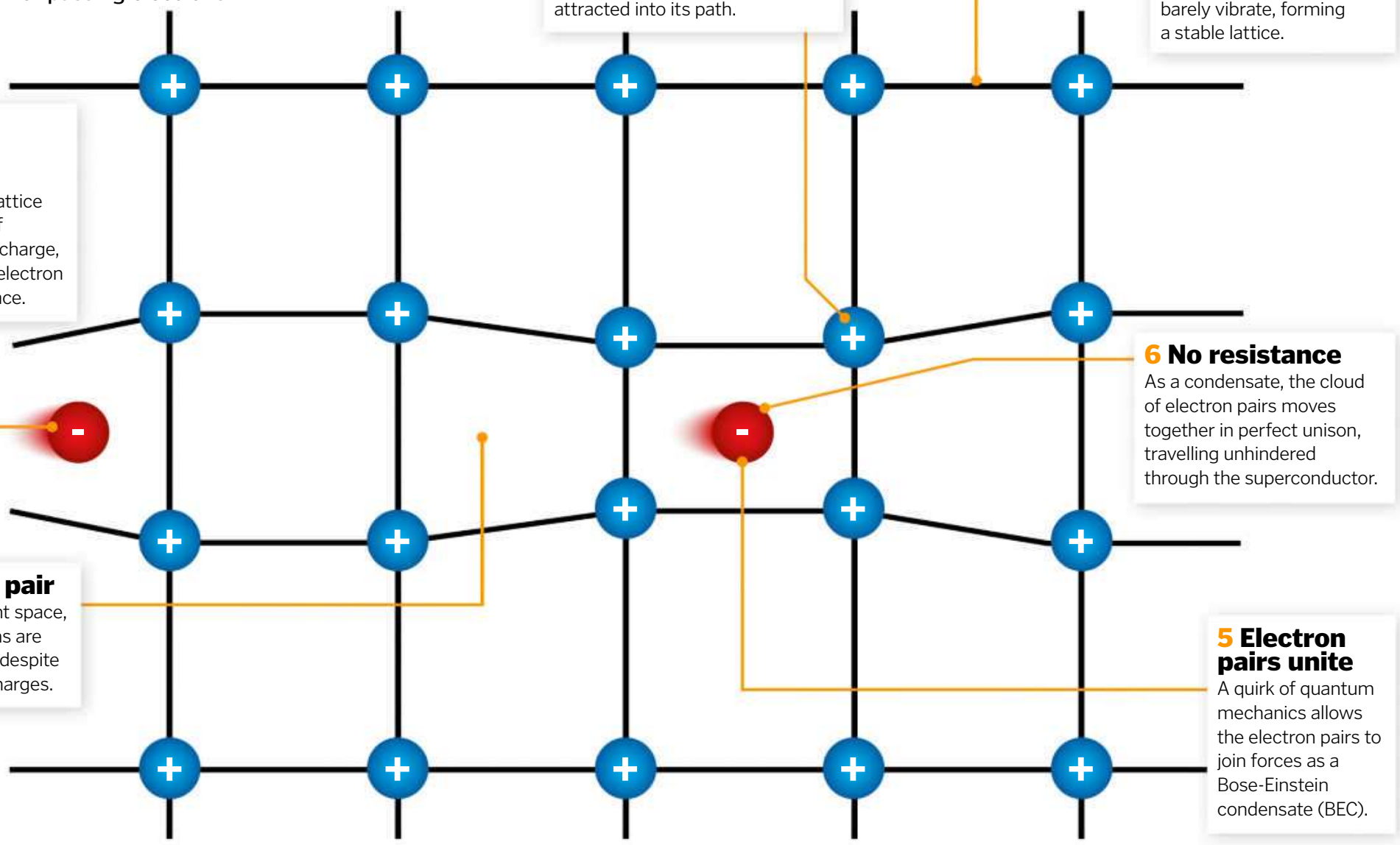
Dutch physicist Heike Kamerlingh Onnes and and his team create temperatures of just above absolute zero and discover that mercury is a good superconductor.

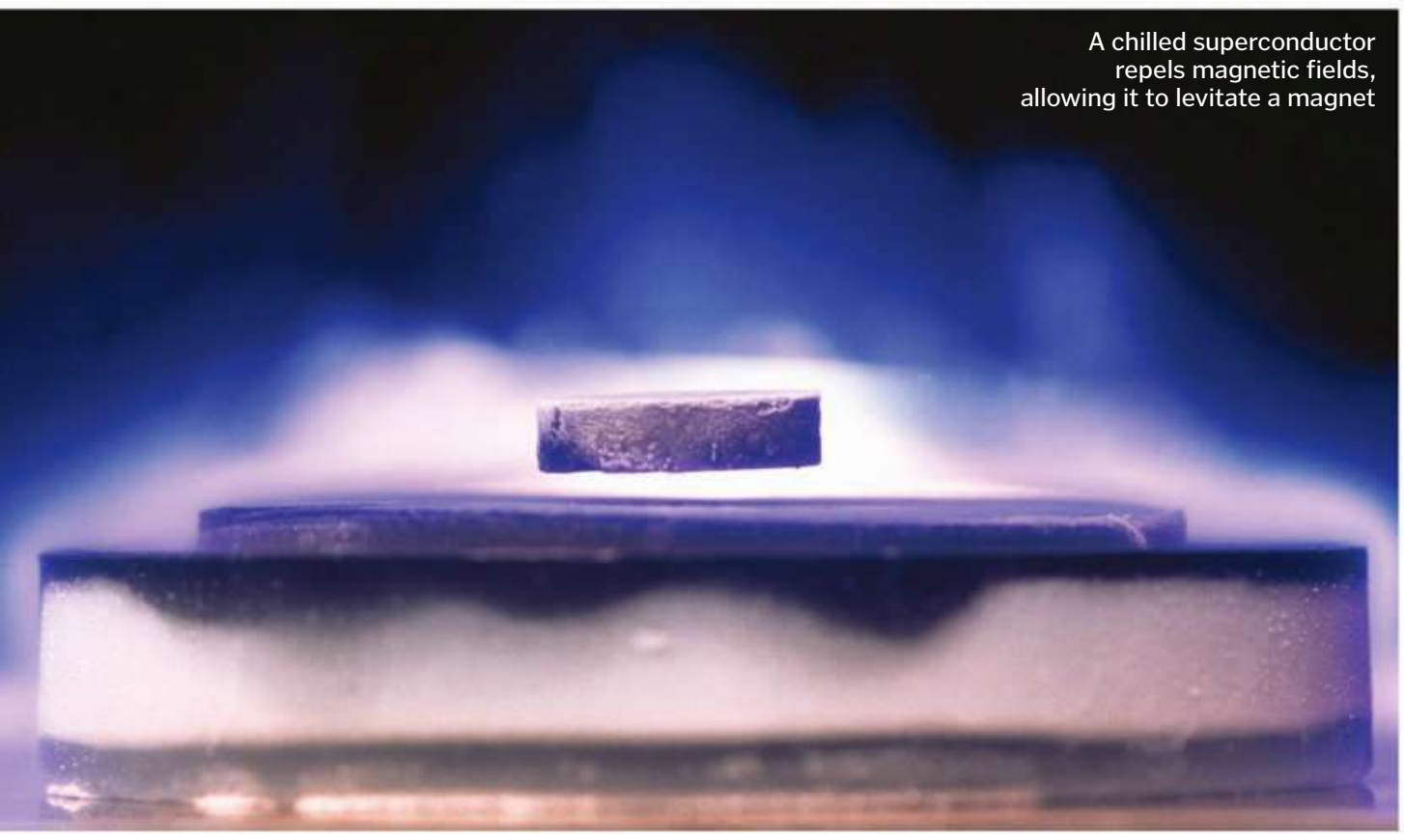
1933
Levitation

Meissner and Ochsenfeld discover the Meissner effect: the uncanny ability of superconductors to repel magnetic fields and cause magnets to levitate.

Superconductor in action

Find out how superconductors make life a whole lot easier for passing electrons


2 Bending the lattice
As a negatively charged electron makes its way through, the positively charged ions are attracted into its path.
1 Frozen lattice
At temperatures approaching absolute zero, the superconductor's ions barely vibrate, forming a stable lattice.
3 Another electron is drawn in
This bend in the lattice creates an area of stronger positive charge, drawing another electron into the same space.
6 No resistance
As a condensate, the cloud of electron pairs moves together in perfect unison, travelling unhindered through the superconductor.
4 Electron pair
Trapped in a tight space, the two electrons are forced together despite their negative charges.
5 Electron pairs unite
A quirk of quantum mechanics allows the electron pairs to join forces as a Bose-Einstein condensate (BEC).



A chilled superconductor repels magnetic fields, allowing it to levitate a magnet

The potential of superconductivity

Despite their impressive abilities, most current superconductor technologies remain chained to high-tech science laboratories, burdened by bulky, energy-greedy and very expensive cooling systems in order to function.

Scientists have set their sights on creating a superconductor that works at room temperature and pressure, which could bring cutting-edge technologies into all of our day-to-day lives. Inexpensive, portable MRI scanners could drastically improve healthcare, while superfast maglev trains would zip up and down the country, reducing travel times.

Replacing our inefficient electrical grids with superconducting cables would slash our electricity bills too. It could also give renewable energies – such as wind farms, which are often located great distances from our cities – a much-deserved boost. Elsewhere, superconductor-enabled electronics could see smaller, faster computers hit the high street.

While physicists have managed to create superconducting materials operational at a temperature of 15 degrees Celsius, they require extremely high pressures, approaching those found at the Earth's centre. Many still believe that the Holy Grail of truly room-temperature superconductors is achievable – it's just a matter of time and patience before we discover it and utilise it in new technology.

© SPL

1935
Brothers London
Fritz and Heinz London reconcile superconductor theory to show that zero resistance and the Meissner effect stem from the same phenomenon.

1957
BCS
Bardeen, Cooper and Schrieffer propose the BCS theory of superconductivity, explaining electron pairing. It earns them a Nobel Prize.

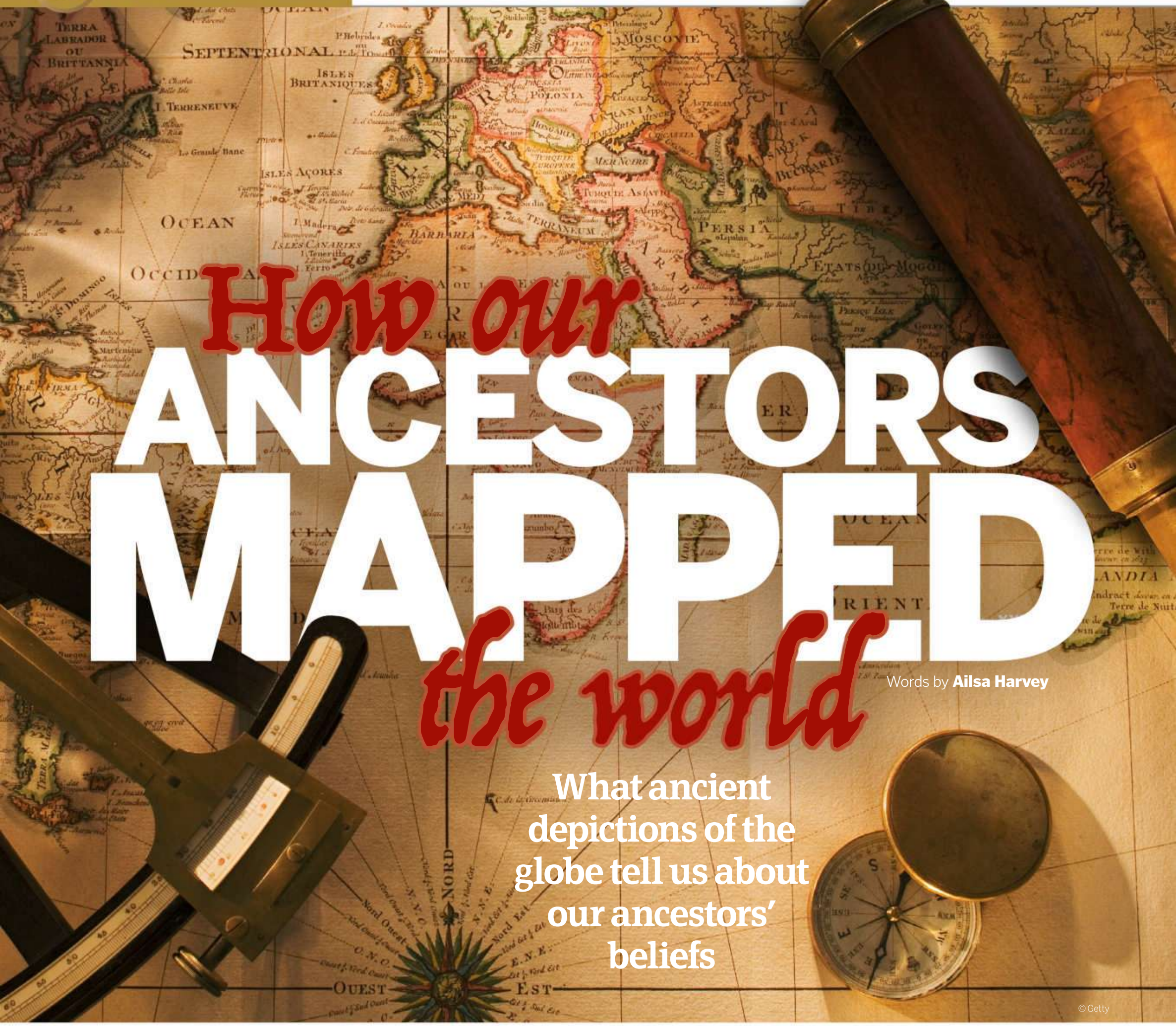
1986
Hot stuff
Bednorz and Müller discover the first 'high-temperature' superconductor, which works its magic up to -243.15 degrees Celsius.

2020
Hotter stuff
A metallic compound made of hydrogen, carbon and sulphur exhibits superconductivity at 15 degrees Celsius – but at extreme pressures.

How our ANCESTORS MAPPED the world

Words by **Ailsa Harvey**

What ancient depictions of the globe tell us about our ancestors' beliefs



© Getty

Is there such a thing as a totally accurate world map? Thanks to a combination of photographs taken from space and careful calculations, it might appear so. But in reality, no map is completely accurate. When images from each angle of the globe are captured, the shapes and lines that make up continents and the jagged borders that form the borders between land and sea need to be flattened.

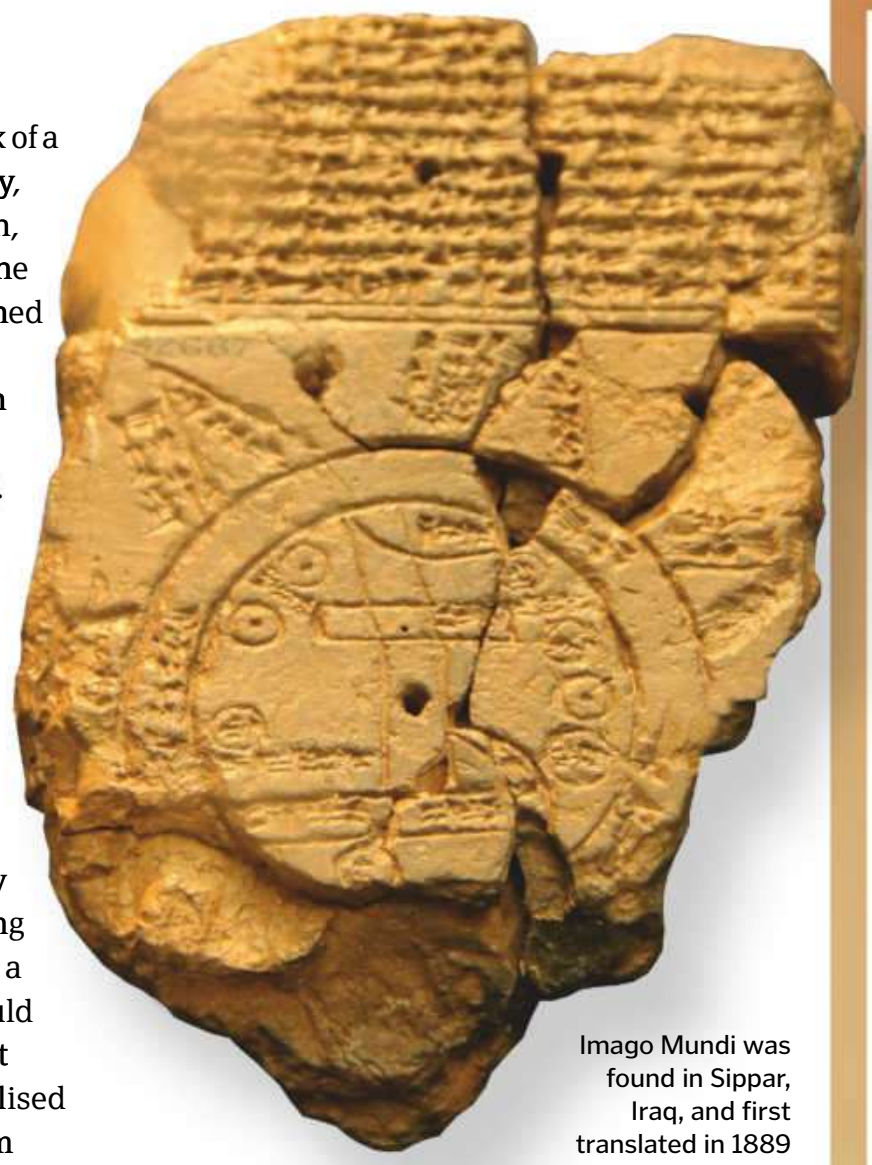
The most common world map today is called the Mercator projection, and while this has been accepted for its accuracy, it's actually filled with compromises. In order to make a spherical object fit a flat, rectangular space, latitudinal lines have been straightened. As a result, land masses have become distorted from their true size and shape. For example, Antarctica appears to be a giant in comparison to Australia, when really they are similar in size.

You might now feel as though you have been misguided during your school geography classes, but our drawn depictions of the world have come a long way. Technology gives us the confidence that we have at least included the total surface area of the globe, and we can use other sources to learn the true sizes of each country. Rewinding to over 2,000 years ago, the maps produced by leading scientists would be unrecognisable to those we use today. Putting aside the task of producing an accurate map today, imagine the difficulty faced by those who had never crossed the seas. With no idea of the immensity of the planet – and without the knowledge that Earth was a sphere – the only world that mattered to most was their own town or country. They might have seen land across the water, but with no way of making sense of it, they told stories of the beasts who might live there and incorporated them into the drawings.

Maps have evolved as our knowledge of the world has expanded. From when the whole world was made up of just a handful of cities to the maps combining myths and geography in equal parts, these are some of our attempts to map the world over hundreds of years.

OLDEST WORLD MAP

600 BCE When you think of a world map today, you likely imagine a paper thin, foldable sketch. But perhaps one of the reasons this map remained largely intact for so long is that the Imago Mundi – also known as the Babylonian Map of the World – is a chunky clay tablet. Carved into this block is an ancient vision of the world. Babylon is placed at the centre, with a ring of sea circling it. As the oldest known map of the world, the area it covers is limited. But this was the world known to the Babylonians: a relatively accurate geographic positioning of the land they had traversed, a narrow band of water as it would appear from land and the eight regions beyond it, either visualised or imagined. The world to them comprised just seven cities.



Imago Mundi was found in Sippar, Iraq, and first translated in 1889

Source: Wiki/© Gary Todd

Reading Imago Mundi

What terrestrial features are engraved in the clay?

Outer regions
The description of five out of the eight surrounding triangles have survived. Makers of this map believed mythical beasts and gods lived beyond the sea.

Mountains
A curved line creating an area inside the ring of sea is labelled 'mountain'. This is believed to be the Zagros Mountains – a 990-mile-long mountain range.

Cities
These small circles represent surrounding cities, including Assyria (4), Der (5) and Susa (8).

Babylon
Intersected by the Euphrates River, which crosses the centre of the map vertically, is Babylon. This is represented by a large rectangle.

Sea
The sea is carved as a surrounding ring, given the label of 'bitter river'. This band of water separated the land they were familiar with from mysterious islands.

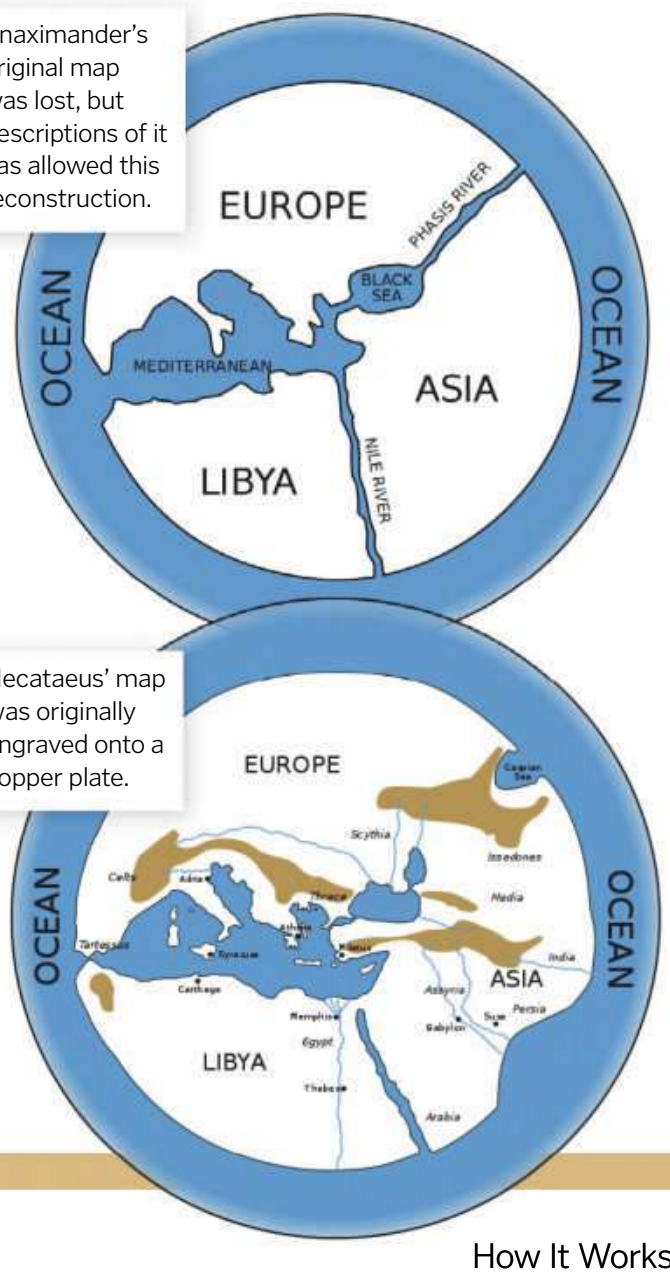
Swamp and outflow
At the mouth of the Euphrates River, a strip separates horizontally into the 'swamp' (7) and the 'outflow' (9).

THE MAPS OF ANAXIMANDER AND HECATAEUS

610 to 476 BCE At first glance, Anaximander's world map is extremely similar to the early Babylonian map. However, the crucial difference comes when observing the areas covered. The ancient Greek philosopher was the first known person to attempt to map out all known inhabited land. This included three continents and the sea that surrounded and separated them. Europe is drawn in the upper half, Asia towards the right and Libya in the bottom-left section. The map was published to improve navigation of the Mediterranean Sea and Black Sea, and depicted a cold north and hot south. Beyond his 2D maps, Anaximander was the first to state that Earth can exist by itself, and doesn't rest on top of something else.

Inspired by Anaximander, Hecataeus set out to build upon his map and make it more accurate. Based on his own travels around Europe, Asia and Egypt, he added more details. Venturing further inland, he noticed the continents connecting in places where Anaximander had portrayed them to be separated. While Anaximander focused only on the position of these large bodies of land, Hecataeus furthered knowledge of the countries within these continents.

Anaximander's original map was lost, but descriptions of it has allowed this reconstruction.



Hecataeus' map was originally engraved onto a copper plate.

Source: Wiki/© Bibi Saint-Pol

Source: Wiki/Balkanique

With exact coordinates, it was possible for exact replicas of Ptolemy's map to be drawn

PTOLEMY'S CALCULATIONS

150 CE Astronomer and geographer Claudius Ptolemy transformed the way maps were created when he became the first person to use maths to scale locations. Helping to inform map makers of the planet's true size, Ptolemy provided coordinates for all of his maps' labelled positions. In doing this he invented longitude and latitude measurements, finding these values for around 8,000 locations.

Previously, map makers had decided the size of places based on their perceived geographical or religious importance. Putting a grid onto his maps enabled Ptolemy to work out distances terrestrially and celestially, as his passions also lay in the stars. The distance from the equator was calculated by studying the length of the longest day of the year there, while positions east and west were measured in time. 15 degrees was found to be about equal to a one hour difference in the Sun's position.

As an astronomer, Ptolemy was keen to show the curved nature of the globe in his map, but not by distorting the distances between locations. It was later discovered that many of his calculations were inaccurate, but he opened doors to more informative methods when he published his techniques in a book titled *Guide to Geography*.

5 FACTS ABOUT TODAY'S CARTOGRAPHY TECH

1 Aerial photography
Modern drones have made surveillance of large areas much easier than it was previously. This real-time footage can create visual records of changes to the geography of Earth.

2 Sensors
When mapping the planet's properties, sensors can instantly pick up changes. Converting sound, light, heat and motion into electrical signals, change detection maps can be made.

3 GPS
The Global Positioning System uses orbiting satellites to provide accurate feedback on the location of a device. When creating new maps this comes in handy, as it can provide the precise path that land surveyors have taken.

4 Satellites
Watching from space, satellites are constantly storing footage of the world. This data can be used for speedy updates of large portions of the planet.

5 Geographic Information System
After sensors, satellites and GPS have collected the data, this system is needed to organise it. It can take different types of data and put the information together to provide a clearer visualisation.

THE T AND O MAP

T and O maps are typically displayed with east at the top

Source: Wiki/Isidore of Seville

636 CE The medieval T and O map was given its name based on its most prominent features. The 'O' refers to the outer circle of the ocean, while the 'T' shape – the River Nile and Mediterranean Sea – creates the separation between Asia, Europe and Africa.

As described by the 7th-century scholar Isidore of Seville, this portrayal of Earth represents only one-half of the globe. While it was believed that Earth was spherical by this point, it was also thought that nobody was able to venture to the lower half – the equator was a burning death trap. Because of this belief that the Southern Hemisphere was uninhabited, it seemed unnecessary to draw it on a map.

WORLD'S LARGEST MEDIEVAL MAP

1300 Spanning 1.59 metres in length and 1.34 metres wide, the Hereford Mappa Mundi is a large piece of calf skin packed with over 500 detailed ink drawings. Preserved to show extraordinary detail, the extensive map shows how both religious texts and geographical information were combined to form its makers' vision of the world. Oriented with east at the top, the map displays 420 towns, 15 religious events, 33 animals and plants and eight classical mythology scenes.

Designed in Europe during the late 13th and early 14th centuries, this is by no means a depiction of the general view of the world, but of Christianity's alone. Many of the spiritual references found on the map, and the locations given most attention, line up with those in the Bible.

Historians believe that this work was produced by a group of artists, perhaps two or three, while the writing was completed by a single hand. The largest cities drawn include Paris and Rome, while Hereford – the city it resides in – is added as a small dot, perhaps even as a late addition.

E

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Paradise
At the top a ring of fire is drawn, with the centre depicting paradise. Due to paradise being drawn where Japan should be, this image was printed in Japanese textbooks during World War II.

Jerusalem
Signifying its importance to the creators, at the centre of the map is Jerusalem, with a crucifix drawn just above.

Caspian Sea
Showing that this map doesn't exactly follow the geographical knowledge of the time, the Caspian Sea appears to connect to the surrounding ocean.

Noah's Ark
A portrayal of this famous biblical story can be found on the border between Armenia and Turkey.

The Red Sea
This large section has been coloured in red to show where the Red Sea lies. The bottom section has been separated in reference to the story of Moses parting the sea.

Egypt
Rivers are carefully plotted onto this medieval map; the River Nile can be seen leading through the centre of Egypt. This image, a coloured copy of the map, shows a close up of the Nile in blue. Mythical creatures, as well as animals such as the rhino, are drawn inside Egypt.

Great Britain
Surrounded by red ink, at the northeastern border of the map are the British Isles. The top-left section shows Scotland, the larger section on the right is England and Wales and the strip below represents Ireland.

Greece
Mount Olympus, Athens and Corinth are all illustrated in this area, allocated to Greece.

Italy
If you tilt your head to the left you can make out the beginnings of the boot of Italy. Directly to the right, surrounded in black ink, is a large triangle: the island of Sicily.

Balearic Islands
With Africa on the right and Europe on the left, the three white triangles among the black ink of the sea are the Spanish islands of Majorca, Menorca and Ibiza.

Source: Wiki/© Scott Ehardt

An aerial view of the famous 134-metre-long condor

© Getty

© Getty

Mystery of the Nazca Lines

A lizard, llama and spider connected by a series of criss-crossing lines… whatever could it mean?

Over 1,500 years ago, the ancient Nazca Indians began to create a series of perfectly straight lines, geometric shapes and over 70 beautiful plants and creatures, ranging from a hummingbird, a dog and a running monkey to a cactus, a flower and a tree, across the dry plains between the Pacific coast of southern Peru and the Andean foothills.

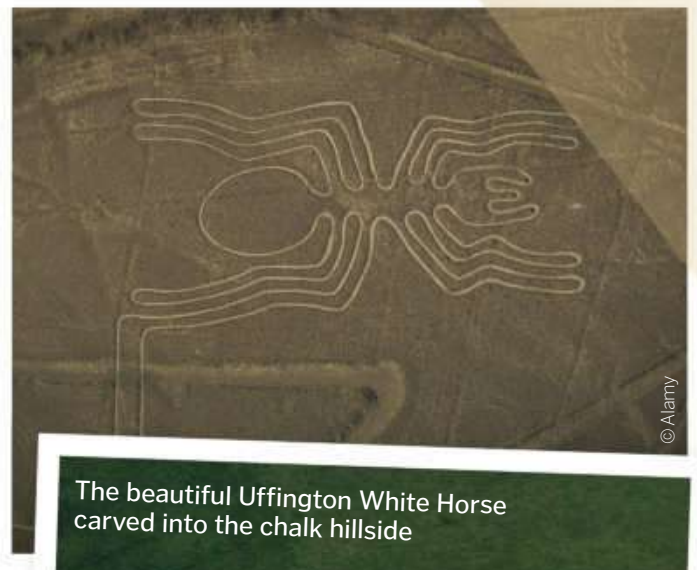
The Peruvian archaeologist Toribio Mejía Xesspe was the first to discover the lines in 1926, but it wasn't until commercial planes flew regularly over the land in the 1930s, catching sight of the magnificent images from the sky, that the general public were made aware. From the ground the lines are extremely hard to make out, but by looking down upon them from above, the geometric shapes, zig-zagging lines and crazy wildlife come into view.

In order to draw the images, the Nazca people carefully scraped away the top layer of rust-coloured iron oxide-coated rocks, revealing a contrasting lighter coloured sand that glows in the midday sunlight. Thanks to the hot, dry climate, the images have remained largely undisturbed since the day they were created.

No one is exactly sure what the lines were made for, and many strange theories have been raised, including the idea that the lines depict a giant astronomical calendar and the animals represent clusters of stars in the night sky.

During the 1960s, some researchers even thought that the criss-crossing pattern was a landing site for visiting aliens, and that one image in particular depicted an ancient astronaut. Today people believe that they were created as part of a ritual to the gods in order to pray for much needed rain, and that the animal images are symbols of fertility and water. Whatever their purpose, they are a constant source of fascination, and in 1994 they were designated a UNESCO World Heritage Site.

A terrifying elongated spider spreads across the landscape



© Alamy

The beautiful Uffington White Horse carved into the chalk hillside

© Getty

The peculiar hill figures of England

The Nazca Lines are not the only archaeological images etched into Earth's surface. The 110-metre-long Uffington White Horse is a magnificent example of a prehistoric hill figure that can be found in Oxfordshire, England. The horse, carved into the white chalk, appears to be galloping across the green hillside. Others include the Westbury White Horse of Bratton Down and the Red Horse of Tysoe, so-called because the underlying soil was red clay rather than chalk. Later examples were created throughout England during the 16th and 17th centuries, including the mighty Long Man of Wilmington, a 72-metre-tall man in Eastbourne, and the Cerne Abbas Giant, a 55-metre-tall colossus storming along the countryside in Dorset. Both hill figures were created by scraping trenches into the grass surface and backfilling the furrows with chalk rubble.

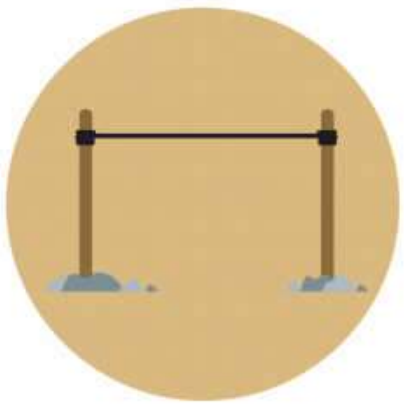
Protected by the land

The lines have stayed largely intact and undisturbed for well over 1,000 years thanks to their location. The dry, dusty plains receive around 20 minutes of rain per year, and with low levels of soft, warm wind, destructive erosion is kept to a minimum. Plaster, found within the soil itself, cools in the early morning mist and acts as a protective barrier to any potential threats.

Illustration © The Art Agency/Nick Sellers

How the Nazca Lines were formed

Archaeologists have spent years trying to understand how the people of Nazca created the patterns



The mysterious lines

Lines were kept straight by using two stakes tied with rope, pulled taut as a guide. The stakes were used over and over again for up to 30 miles.

Perfect spirals

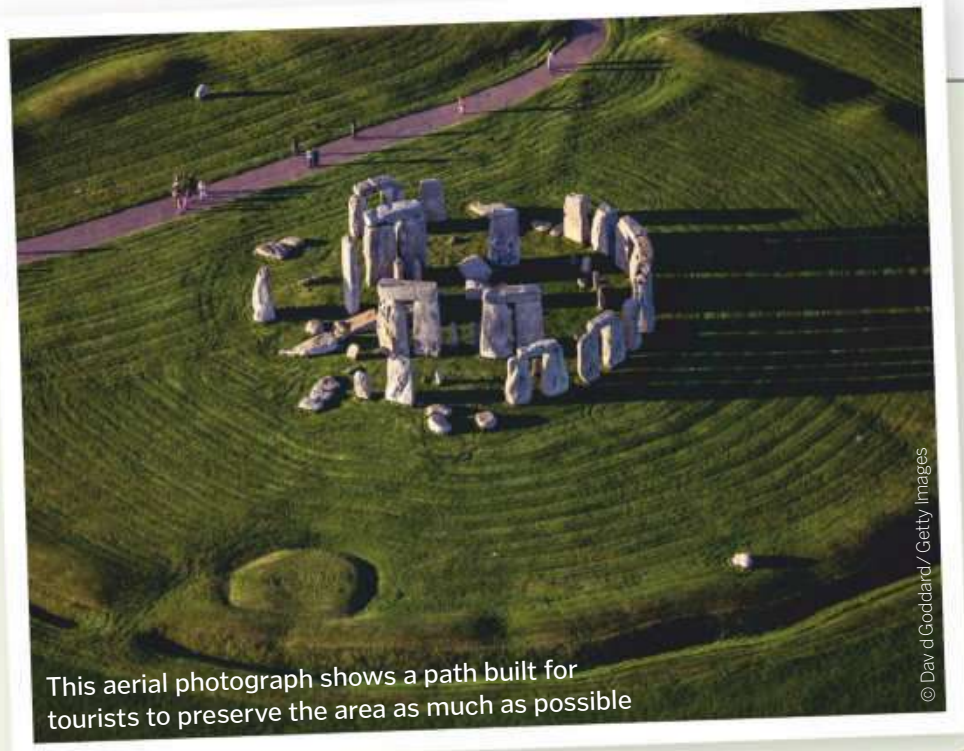
A rope was tied between two stakes while a third was pushed into the ground, forming a triangle. One tied stake was wound around the other two, creating a perfect spiral.

The creature geoglyphs

To begin with, small-scale drawings were made on canvas, which were gradually increased in size on the land and kept in proportion using stakes and rope.

AR ZONE!

Why Stonehenge was built


This aerial photograph shows a path built for tourists to preserve the area as much as possible

© Dav d Goddard/ Getty Images

What can this prehistoric stone circle tell us about Neolithic times?

Even today, as you approach this semi-collapsed ring of towering stone blocks, there is an air of importance radiating from the deserted structure. Powerfully placed on the empty Salisbury Plain of Wiltshire, England, Stonehenge has become an iconic tourist attraction for around a million visitors every year, those seeking insight into the ways of Britain's past. 5,000 years since the monument began construction, much of its origins remain a mystery. Why was this ring of rock transported to this specific location? And what was this structure used for after being so precisely and purposefully built?

The culture that arranged these stones left no written records, making the story of the monument much more difficult to resolve. But as a result of ongoing archaeological investigations, a largely accepted theory is that within these stone pillars, burial ceremonies took place for those of a high social status.

As more clues are unearthed, it is clear that plenty of thought, time and effort went into making Stonehenge. Using the available resources, prehistoric people ventured far and wide to bring the stones to this spot on the plains, making it likely that this place has always held some significance. Twice a year during the summer and winter solstices, the Sun aligns perfectly with the 'heel' stone when viewed from within the circle. This large stone was placed just outside the outer ditch circle. During the two events, people flock to the circle to observe the result of its builders' precision.

The main reasons our ancestors constructed this creation can only be imagined as you observe its beautiful, complex design. As time goes by, the ongoing discoveries that are made by archaeologists in and around the site are slowly helping us to better understand the neolithic culture that built it..

Mapping the monument

Piecing together the iconic, rocky remains

Upright sarsens
Though they seem precariously positioned, some of these nine-metre-tall stone slabs have remained standing for thousands of years. Their exact purpose is unknown, but together they produce an interesting ringing acoustic when hit. These ringing rocks were believed to have healing properties by some ancient cultures.

NOW

Fallen or broken bluestones
These broken stones show where the bluestone gets its name. All from the Preseli Hills of southwest Wales, these stones display a bluish tinge when wet or broken.

Fallen sarsens
The larger stones that make up Stonehenge are made of silcrete rock. Weighing up to 30 tonnes each, these were transported across 20 miles of land from Marlborough Downs.

Ditches
These were dug with antler tools. Many historians believe that the outer ditches may have held timber posts.

Stone holes
Stonehenge is incomplete, with multiple holes in the ground indicating where these huge blocks used to be. Parch marks were discovered in 2013, showing where large sections of stone had prevented the grass roots from growing.

AR ZONE! SCAN HERE

Advanced architecture

The construction of such a substantial structure during the Neolithic Period would have been much more strenuous with the limited technology of the time. How people were able to transport the materials and create a burial site that still stands tall today is more impressive than the structure itself. It would have taken around 1,500 years from start to finish, as features were added in about six significant stages over this time.

Before the rocks could be positioned, they had to be sourced. Although some believe ancient glaciers would have carried these huge blocks nearer to the site, the most common theory is that people pulled or rolled these stones from as far as Wales. These slabs would then be placed into a hole and pulled upright using ropes and a frame. Once vertical, the hole would be packed tightly with rubble, keeping the tower firmly in position. To keep the balancing stones secure, mortise and tenon joints were carved into the rock. These are protruding pieces of rock pointing upwards from the top of vertical slabs into holes made in the bottom of the horizontal rocks, which keeps them from sliding apart.

This illustration shows how the joints work to connect the stones in the outer circle

© Getty Images/Heritage Images

Upright bluestones
Within the larger sarsens are much smaller blocks of bluestone. One-sixth of the weight of the larger stones surrounding them, these were arranged in a double arc between the two sarsen stone horseshoes.

Post or stake holes
Lined up over 15 metres from the northeast entrance, a neat line shows where posts once crossed the path. At the gap in the outer ditch there's a rectangular and concentrated arrangement of these holes. These could have been created over time to hold scaffolding posts in order to erect the stones, or they may be more culturally significant. Historians think they could have been used to hang bones or offerings for spirits.

Cremation sites
The remains of cremated bodies have been found in these spots. 58 ancient people were found in 1919, after having been stored in containers that have now decomposed. Scientists now know that they were buried during the early stages of construction, between 3000 and 2480 BCE.

Burial sites
Experts believe those who were buried beneath these stones held importance at the time. The skeletons were originally all thought to be adult men, but further investigations have shown them to be men, women and children, as well as one newborn.

Raised banks
Serving as a wall surrounding the burial chamber at the centre, these raised banks trace the perimeter. They were created from displaced earth from surrounding ditches.

THEN

Illustration © Nicholas Forder

Stonehenge is older than all the pyramids in Egypt

© Grant Faint/ Getty Images

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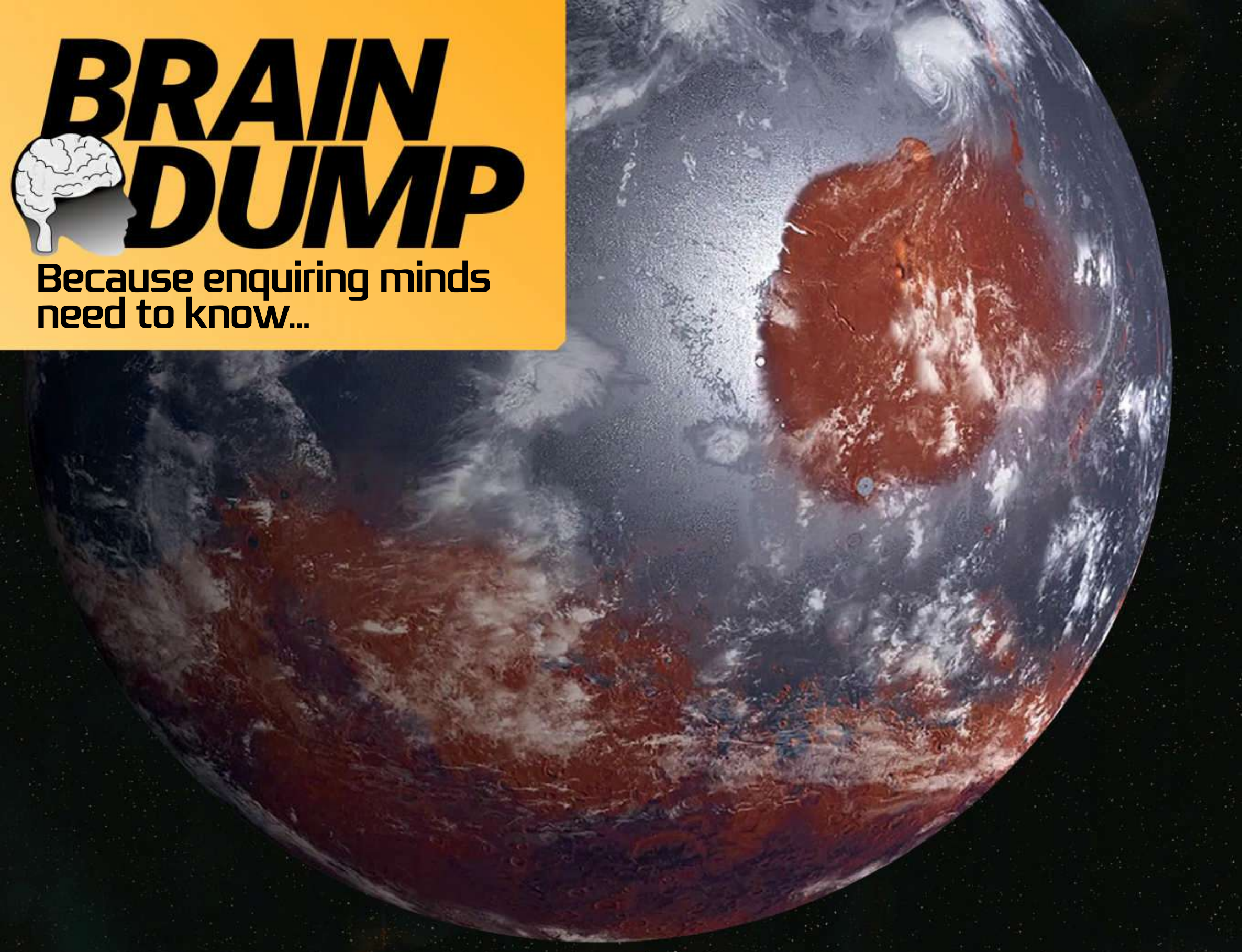
BRAIN DUMP

Because enquiring minds need to know...



SPACE

Do you think we will see humans landing on Mars in our lifetime? And will we ever attempt to terraform it?

Kareem Dennis

NASA's 2024 mission to the Moon is a stepping stone to a human mission to Mars. It's possible that Mars will happen within 50 years, but there's a huge difference between going to the Moon and going to Mars: three days compared to seven months in travel time, let alone the extra supplies and other considerations a Mars trip requires. We won't see terraforming in our lifetime, unfortunately. NASA recently sponsored a study that concluded Mars terraforming isn't possible with present-day technology and that "there is not enough CO_2 [carbon dioxide] remaining on Mars to provide significant greenhouse warming... most of the CO_2 gas is not accessible and could not be readily mobilised." **BB**

An artist's impression of Mars as we think it might have been billions of years ago, when it had oceans and a thicker atmosphere © NASA

WANT ANSWERS? Send your questions to...

How It Works magazine | @HowItWorksmag | @howitworks@futurenet.com

SCIENCE

How is energy stored in normal batteries you can buy in the shops?

Louise Tyndall

A common battery, like the AAs you can buy in the shops, has three parts: a positive electrode, a negative electrode and an electrolyte – a chemical medium that separates the electrodes. A chemical reaction between the positive and negative parts generates an electrical charge with the help of the chemical reagent. When the reagent runs out, it stops producing the charge.

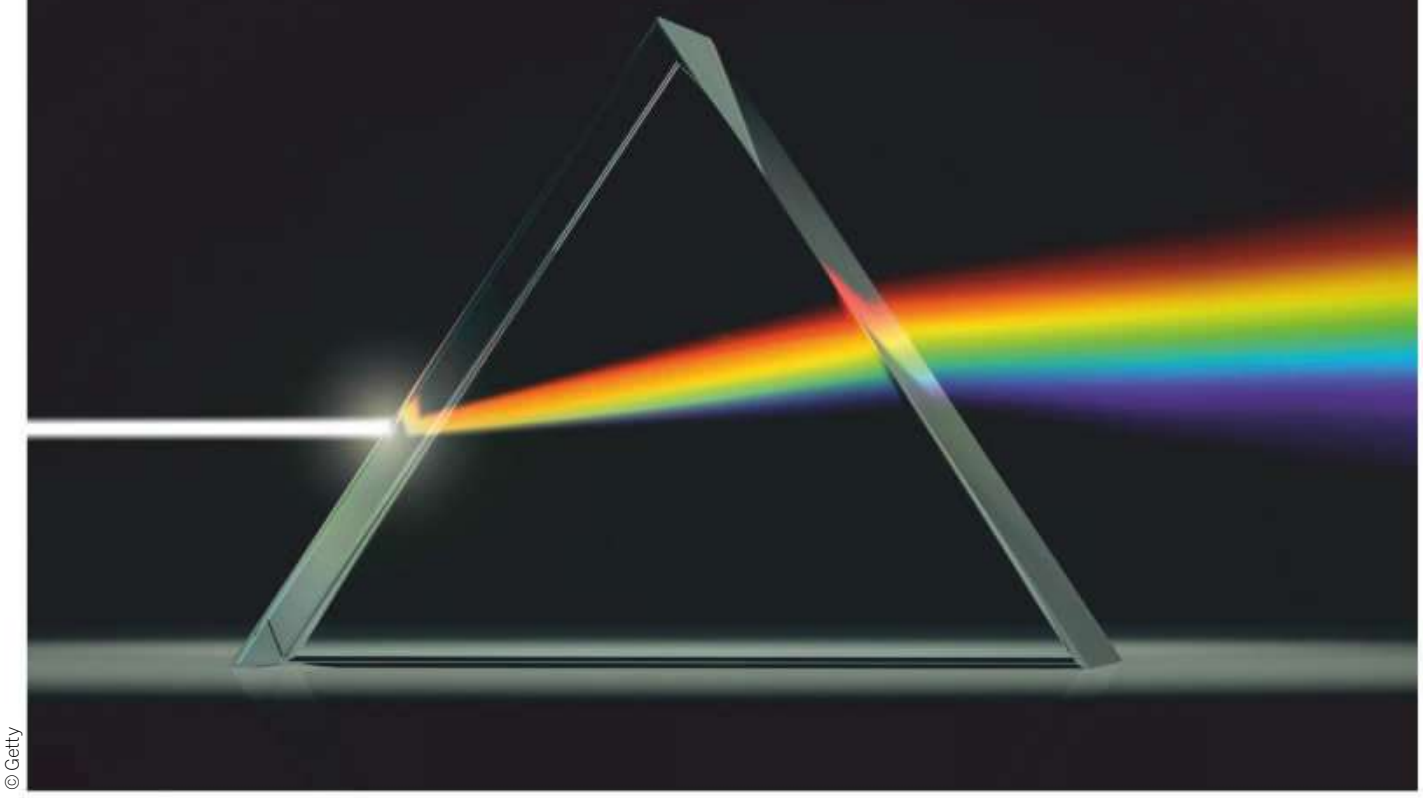
This means that a battery doesn't store the energy itself, but rather the potential to produce it. A rechargeable battery typically uses lithium-ion as a chemical reagent, which allows the process to be reversed, turning charge back into chemical potential. **SD**

© A amy

Is black a colour, scientifically?

Archie Swain

Black can be created in paint using a combination of all shades, so it's often classed as a colour. However, because physics describes colour as a range of visible light, and black is an absence of light, scientifically it is not a true colour. **AH**



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ENVIRONMENT

Why do different herbs taste different?

Ellie Meredith

Although all herbs come from the leaves of aromatic plants, they all taste different because of their chemical composition. For example, thyme has a chemical called thymol to give it its unique flavour, whereas basil contains a chemical called estragole. **SD**

DID YOU KNOW?

Rainforests produce 28 per cent of Earth's oxygen supply

© Getty

SCIENCE

If a vaccine is 95 per cent effective, what happens to the five per cent it doesn't protect?

Stephen Conn

The efficacy of a vaccine like the coronavirus vaccine is whether it protects a group of patients under controlled conditions, like in a laboratory. The effectiveness of a vaccine is how it performs in the real world. In your example, 95 per cent effectiveness would mean that 95 out of 100 people who are given the vaccine wouldn't be infected by the virus if they were then exposed to it. The other five could be infected. **BB**

BRAIN DUMP

The pipes used in glassblowing are 1.2 metres long

© Getty

SCIENCE

How does glassblowing work?

Jeff Jacobs

Glassblowing involves blowing air into molten glass and shaping it before it cools and solidifies. Using a long pipe to separate the glassblower from the heat, it is dipped into a furnace of molten glass. Due to the extreme heat, the mouthpiece is submerged in cold water until the blower takes position. As air travels into the ball of molten glass at the bottom of the pipe, it expands from the middle, creating a growing bubble. While blowing, the glass is rolled and shaped depending on the desired design. Timing can make or break these glass artworks, but if the temperature drops to the point where glass is unworkable, it can always be reheated. **AH**

© NASA

SPACE

How many atoms are there in the universe?

Max Hall

Scientists estimate there are between ten quadrillion vigintillion and one hundred thousand quadrillion vigintillion atoms in the observable universe. That's between 10^{78} and 10^{82} atoms. **BB**

DID YOU KNOW?

Atropine is named after a Greek goddess who chose how people died

© Getty

ENVIRONMENT

Why is atropine so deadly?

Catherine

Atropine can be prescribed to manage heart rate, clear airways for surgery or as an antidote for some overdoses. To do this it interferes with the parasympathetic nervous system, which conserves energy. High doses of atropine increase the heart rate to deadly levels.

It is a white powder that comes from the roots of the deadly nightshade plant, and can be dissolved in water in equal volumes. 100 grams of the odourless powder can hide in 100 millilitres of water, maximising its deadly potential. **AH**

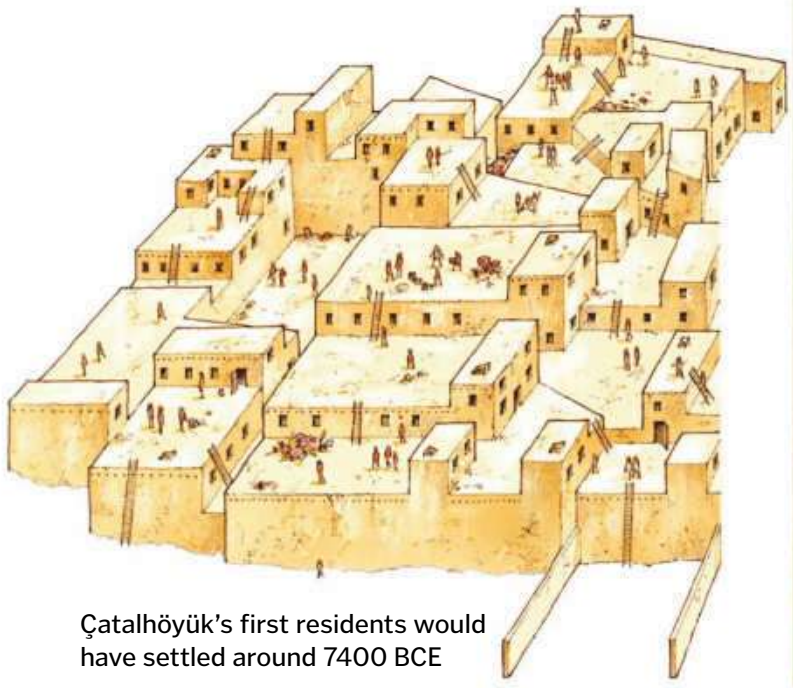
© Alamy

ENVIRONMENT

How do different coloured plants photosynthesise?

Ellie Meredith

Green-leafed plants are filled with a pigment called chlorophyll that converts sunlight into a food source and reflects green light. Yellow and red-leaved plants have a higher concentration of pigments called carotenoids, which work with chlorophyll to achieve photosynthesis. These carotenoids reflect other wavelengths of light than green and appear in different colours, predominantly red or yellow. There is another pigment called anthocyanin which turns leaves purple. It works in the same way as carotenoids do, but reflects purple light. **SD**



Çatalhöyük's first residents would have settled around 7400 BCE

HISTORY

Where was the first village settled?

Mike Cooley

It's believed that the first evidence of a human settlement is in Turkey over 9,000 years ago. Known as Çatalhöyük, the ancient village was uncovered by archaeologists on the Konya Plain back in the 1960s. It housed a Stone Age society of as many as 8,000 villagers. Homes were not as we recognise them now: they had no doors and windows and would have been accessed through their roofs. Villagers would have been keen farmers and agriculturists, beginning humankind's journey to modern-day life. **SD**

© Getty

© Getty

ENVIRONMENT

What is the world's most toxic plant?

Katie Langley

Oleander is often regarded as the most poisonous plant. Containing several types of poison in all parts of the plant, it affects most animals and humans. Eating a single leaf can kill, and even ingesting honey from a bee that has taken oleander nectar is enough to poison you. The main signs that you have been poisoned by this flowering plant include vomiting, stomach pain, drowsiness and changes to heart rate. **AH**

Oleander flowers can be pink, red, orange, white or yellow

DID YOU KNOW?

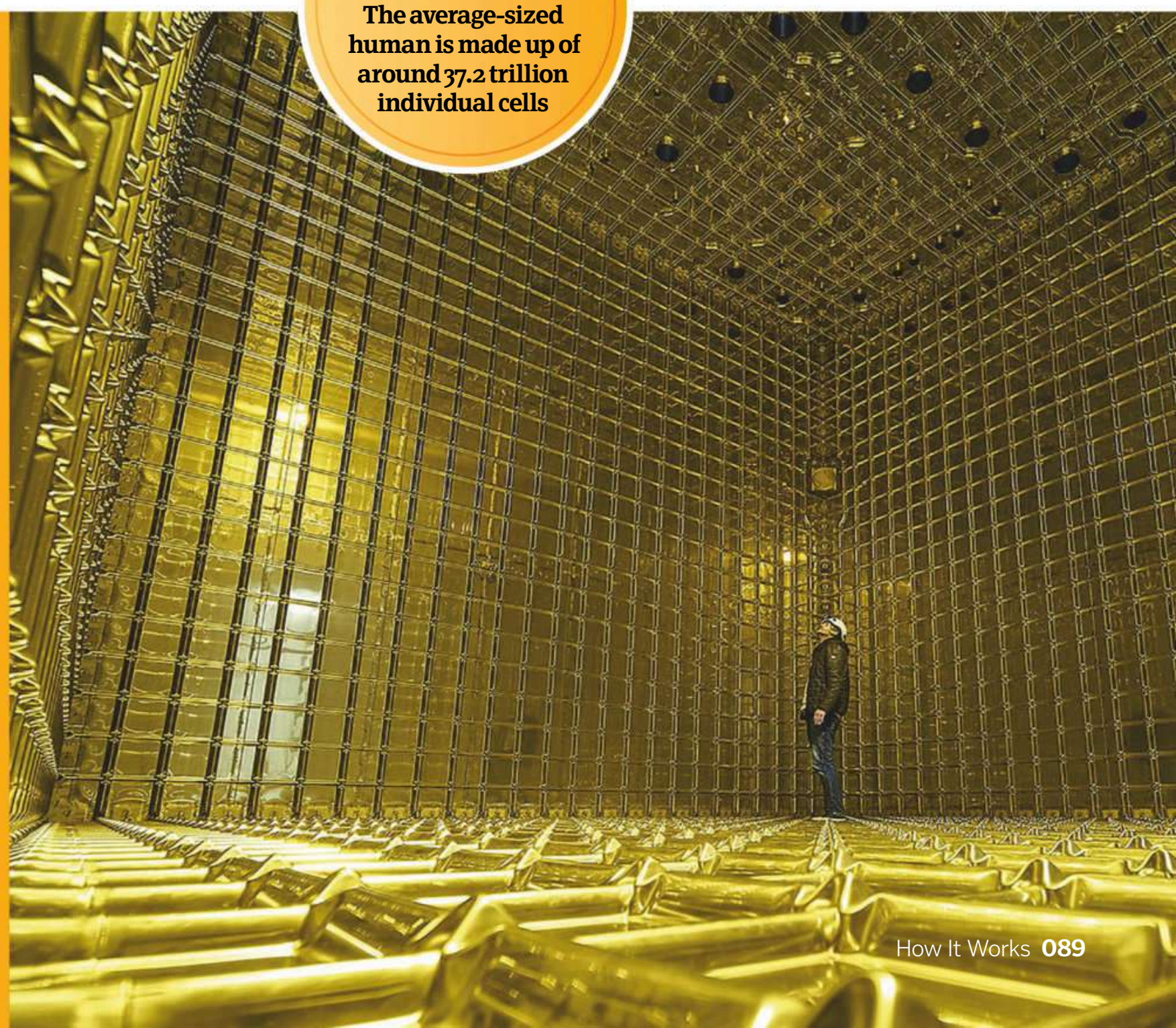
The average-sized human is made up of around 37.2 trillion individual cells

TECHNOLOGY

What is the smallest thing ever seen?

Imelda Ortiz

The smallest thing the unaided human eye can see is about 0.1 millimetres – about the width of a human hair. The smallest thing with mass we've observed are electron neutrinos, which are about 0.000000000000005 the width of a hair. The only way to 'see' these miniscule particles is using very large detectors that are often situated deep underground, like Fermilab, to isolate them from background radiation. **BB**



© CERN

The ProtoDUNE detectors at CERN, the European particle physics laboratory, will attempt to define the nature of the elusive neutrino

BOOK REVIEWS

The latest releases for curious minds

Planes

FROM THE WRIGHT BROTHERS TO THE SUPERSONIC

- Author: **Jan Van Der Veken**
- Publisher: **Prestel Publishing**
- Price: **£15.99 / $19.95**
- Release: **4 March**

Belgian author Jan Van Der Veken is both a pilot and an award-winning newspaper and magazine illustrator, who has put his two passions together to create *Planes*: an illustrated history of human flight with a strong science angle. It's as slick and beautiful as a Northrop Grumman B-2 Spirit.

Charting the history of flight from the Wright brothers to the age of supersonic jets, with each turn of the page the reader will advance an era and discover the next step that engineers and pilots made to advance aviation.

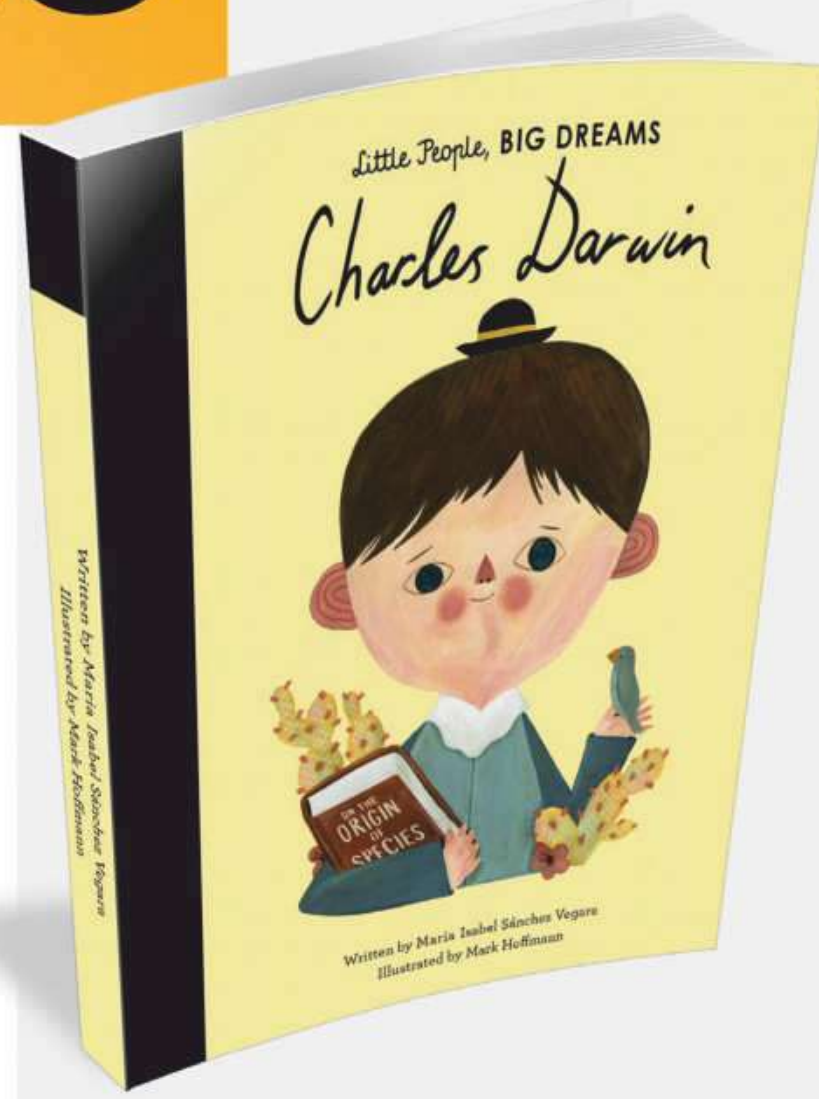
Even the basics of aerodynamics are a complicated subject, so it takes some expertise to distil that into a few simple, comprehensible paragraphs. A page on the mechanics of flight is followed by an example of an aircraft that highlights its generation. The concept of ground effect, for example, was utilised by Russia's Caspian Sea Monster, a massive Cold War-era aircraft that took advantage of the reduced drag experienced when flying close to the surface of the water.

Sometimes there's some science that *Planes* describes in putting these aircraft under the spotlight, but other times there's just a good story behind them – like the mystery of Charles Lindberg's double-propellor Lockheed P-38 Lightning, which went missing with its pilot over the south of France in 1944.

Planes explores the full breadth of aviation theory with explanations of GPS, runway design, the different levels of the Earth's atmosphere, cloud formations and how the experienced pilot might react to various weather conditions. Unless you're flying a NOAA hurricane-hunting aircraft, you'll probably want to avoid flying into those billowing storm clouds. Jan Van Der Veken has illustrated every page with drawings of aircraft or infographics in a retro style that's appropriately reminiscent of Biggles comics, with a simple but striking colour palette.

It's been pitched by publisher Prestel as a book for aviation fans, but *Planes* is both an eye-catching and fascinating read that anyone would enjoy.

Planes explores the breadth of aviation theory


Little People, BIG DREAMS
Charles Darwin
ON THE ORIGIN OF SPECIES
Written by Maria Isabel Sánchez Vegara
Illustrated by Mark Hoffmann

Charles Darwin

MEET THE MAN WHO UNCOVERED THE SECRETS OF EVOLUTION

- Author: **Maria Isabel Sanchez Vegara**
- Publisher: **Frances Lincoln Children's Books**
- Price: **£9.99 / $15.99**
- Release: **Out now**

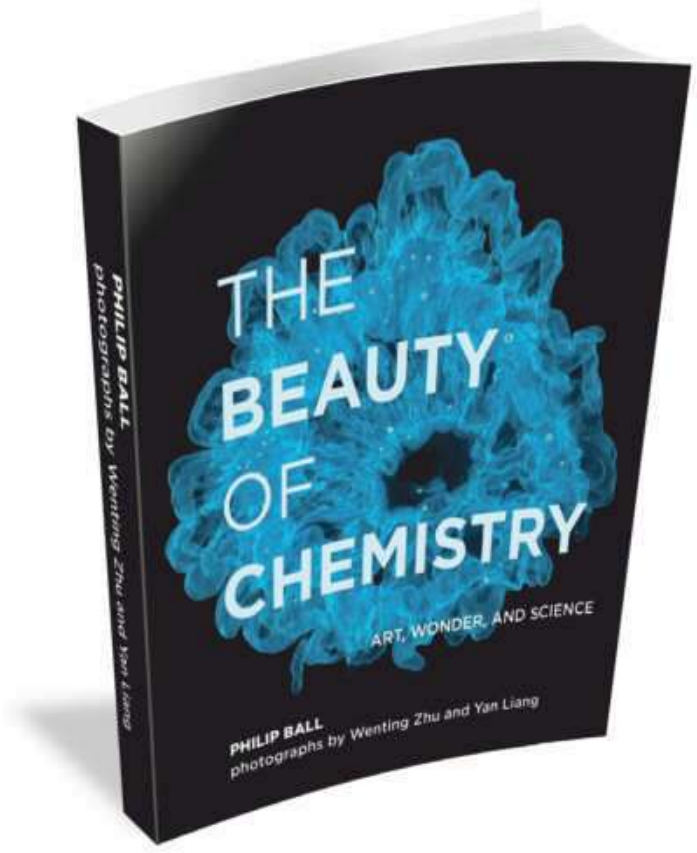
He's one of the most important figures in the study of natural history and evolution, but how well do you know his past? As one of the latest editions in the critically acclaimed *Little People, Big Dreams* series of children's books, *Charles Darwin* tells the story of the life and work of one of the most brilliant scientists who ever lived.

From digging worms in his Shrewsbury garden and almost venturing down the path of medicine to finally boarding the Beagle and setting sail to discover the world, this compact book tells Darwin's story in bite-sized chunks that are perfect for a young audience. Short and snappy text is accompanied by the beautiful and bright artwork of illustrator Mark Hoffmann, which really brings Darwin's story to life. If you're looking to educate your little ones on one of the biggest heroes of science, then this book is well worth reading.

The Beauty of Chemistry

ART, WONDER AND SCIENCE

- Author: **Philip Ball**
- Publisher: **The MIT Press**
- Price: **£36.54 / $49.95**
- Release: **11 May**


PHILIP BALL
photographs by Wenting Zhu and Yan Liang
THE BEAUTY OF CHEMISTRY
ART, WONDER, AND SCIENCE
PHILIP BALL
photographs by Wenting Zhu and Yan Liang

From the beauty of bubbles to the profusion of patterns in nature, this aesthetically pleasing book takes the reader on a journey through the weird and wonderful world of chemistry.

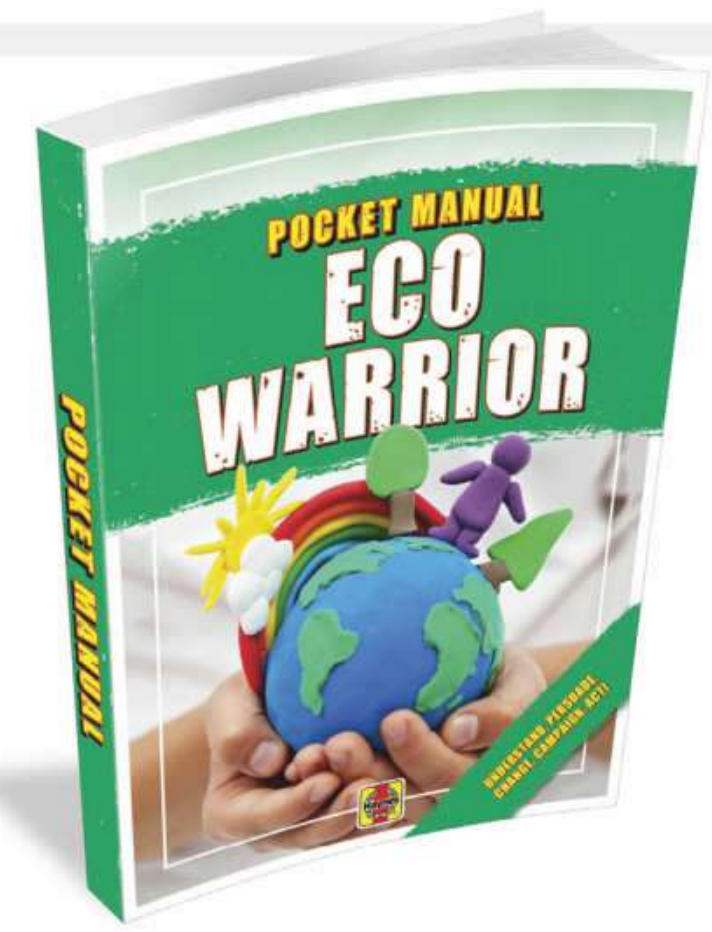
A far cry from any chemistry textbooks you might have read in school, this book is a stunning collection of photography that will leave you in awe. However, it's not just a pretty picture book for the coffee table – it's also packed with scientific knowhow. One of the most surprising takeaways from this book might be the beauty of precipitation. Who knew that dropping different chemicals into water would yield such photogenic results?

It's a book that chemists and science enthusiasts alike would enjoy, but it's so expertly written, without burying the reader under complicated jargon, that anyone can appreciate its insight and imagery.

Eco Warrior Pocket Manual

INSPIRING A NEW GENERATION OF ENVIRONMENTALISTS

- Author: **Catherine Barr**
- Publisher: **Haynes Publishing**
- Price: **£6.99 (approx. $9.50)**
- Release: **Out now**



Learning about our unsustainable impact on the planet can be quite overwhelming for young people. They may feel like they want to help in some way, but where can they start? This pocket manual is a helpful guide for those wanting to understand the big issues surrounding the environment and take the next steps to improvement. Ten of these 'big issues' are categorised in the first section, with key topics to cover all angles. After tackling all-important environmental tragedies, this manual goes on to inspire the next generation with vibrant pages and impactful fast facts.

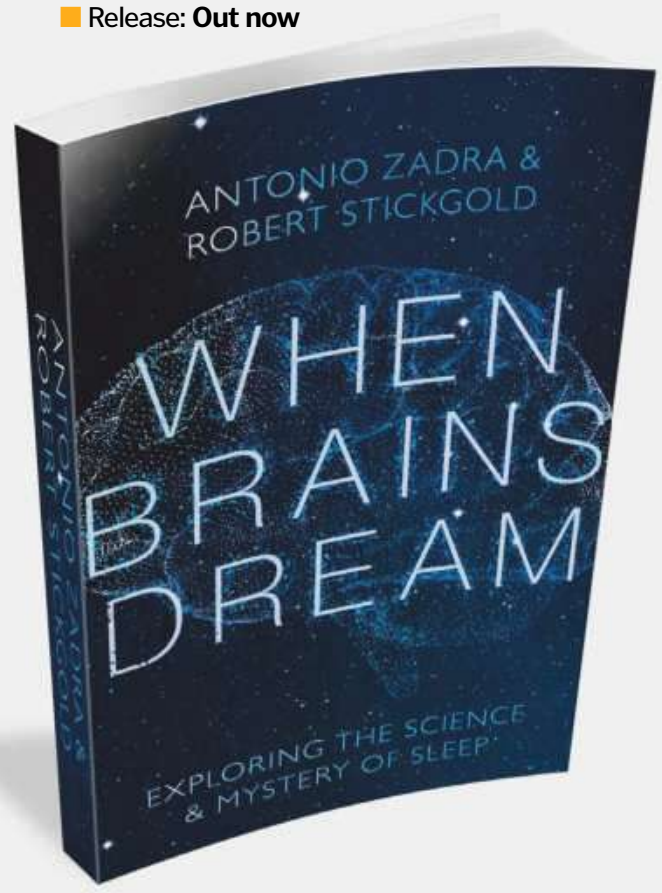
Care has been taken to ensure that young readers are aware of not just the worrying patterns, but also the inspiring environmental pioneers, and that they are equipped with the tools to take action if they decide they want to.

With stories of influential characters who have made a difference, from Charles Darwin to Greta Thunberg, combined with important tips for accurately researching and effectively communicating their views, this book sets the reader up to become the next eco warrior.

When Brains Dream

THE SCIENCE AND MYSTERY OF SLEEP

- Author: **Antonio Zadra and Robert Stickgold**
- Publisher: **W. W. Norton & Co**
- Price: **£20.77 / $26.73**
- Release: **Out now**



Most of us have found ourselves confused by a dream. If you've ever woken up wondering 'why did I dream that?', or 'what goes on in my head while I sleep?' then this is the book for you. Written by two experts on the science of sleep, this book is an exceptional combination of our ancient perceptions of dreaming and the latest scientific discoveries.

Presented in an engaging tone, each chapter helps you understand a different area of the unconscious mind. What impact do traumatic events have on our dreams? And what more are we looking to better understand, such as seemingly prophetic dreams of future events? In addition to science's most recent findings, Zadra and Stickgold present a new model which explores further how dreams utilise our memories and experiences in new and fascinating ways.

Presented in an engaging tone

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 How much of the Solar System's total mass is in the Sun?
- 33 per cent
- 50 per cent
- 70 per cent
- 99 per cent

Q2 Tiny 'water bears' can survive which extreme condition?
- Deadly radiation
- The vacuum of space
- Severe drought
- All of the above

Q3 A fig tree with a world record had roots that went how deep?
- 11 metres
- 122 metres
- 489 metres
- 3,800 metres

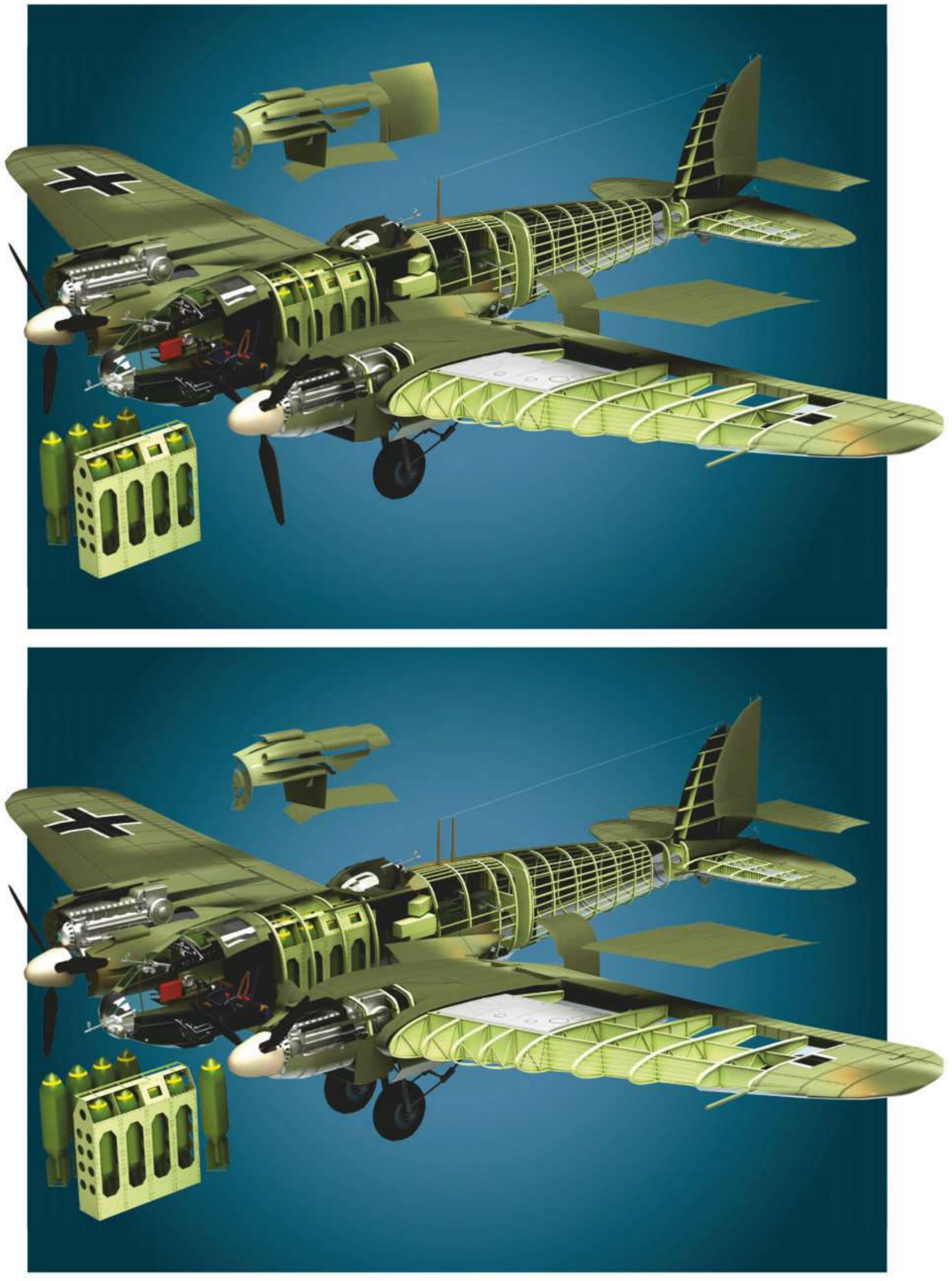
Q4 About how effective is the AstraZeneca coronavirus vaccine?
- 33 per cent
- 50 per cent
- 70 per cent
- 99 per cent

Q5 The metal-hulled steam warships first built in the 1850s were known as what?
- Steelwakes
- Metalcruisers
- Plateships
- Ironclads

Q6 What was Cray-1?
- A supercomputer
- An endangered shrimp
- A criminal gang boss
- A Royal Navy rank

Spot the difference

See if you can find all six changes between the images below



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

4	1		9	6		8	7	2
			7					5
5	9	7	1			3	4	6
	5	2		4		1	3	
7	8	1	3	5	9		6	4
	4		2		1			9
2	3		5			7	9	
	6	5	8	9	7		2	
8	7		4	2		6		1

DIFFICULT

9	6			1				4
4								
	2					8	9	
				9	4	2		6
7		9	2					
					7		5	1
6					1	4		
			9		8		3	
1								5

© Getty

What is it?

Hint: You shouldn't count them before they hatch…

A .....

D	I	P	E	A	Z	N	O	W	S	O	L	L	E	C
A	R	K	I	B	B	A	S	A	L	N	O	A	P	O
I	W	U	N	E	M	S	P	A	C	T	R	O	M	U
U	O	H	I	F	O	A	B	R	M	A	D	Q	I	N
F	N	H	C	D	L	O	K	T	O	V	Y	O	A	H
R	S	R	O	Y	E	N	G	D	R	Y	U	D	O	A
I	A	V	M	A	X	L	I	S	N	Q	A	U	V	Y
C	O	U	R	T	B	I	B	L	L	E	S	L	M	A
A	H	J	I	O	E	S	A	B	T	F	R	I	N	B
S	E	M	F	U	R	N	I	B	U	G	N	O	D	U
A	F	R	I	G	A	T	E	L	L	B	U	B	P	S
P	E	L	S	B	E	C	A	N	R	U	F	O	H	A
U	B	F	R	A	P	A	N	A	S	E	L	L	D	I
M	A	M	E	D	I	C	I	N	E	W	O	N	X	U
I	R	C	E	C	O	U	N	E	Q	U	J	P	A	M

Wordsearch

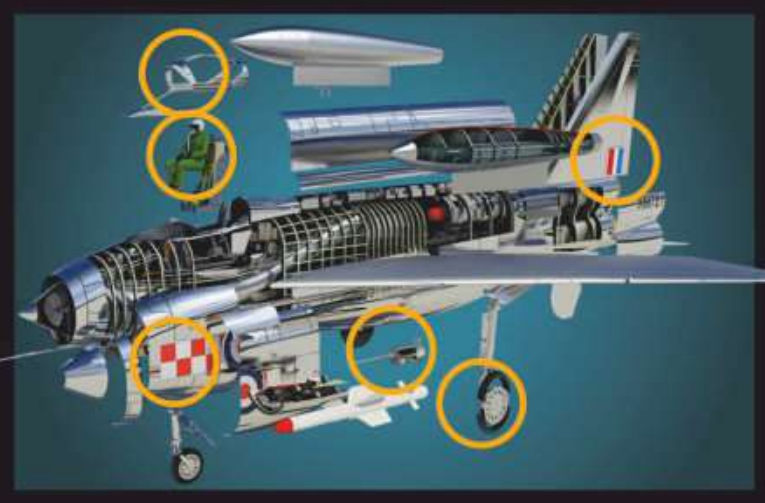
FIND THE FOLLOWING WORDS…

FRIGATE
ROYAL
SNOW
MEDICINE
NASA
BUBBLE
CELL
HAYABUSA
MAP
COURT
FURNACE
DRUID

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 Smallpox
Q2 A solar nebula
Q3 Ten tonnes
Q4 Styling their hair
Q5 Dwarf planet
Q6 Hippocrates

WHAT IS IT? …RING PULL

© Alamy

WIN!
A SPHERO ROBOT

This month we are giving you the chance to win a Sphero RVR, the all-terrain robot created for makers, hackers and coders. This fully programmable robot boasts onboard sensors, an accelerometer and gyroscope to give you the freedom to go anywhere and do anything

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For your chance to win, answer the following question:

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a) **Marie Curie** b) **Charles Darwin** c) **Brian Cox**

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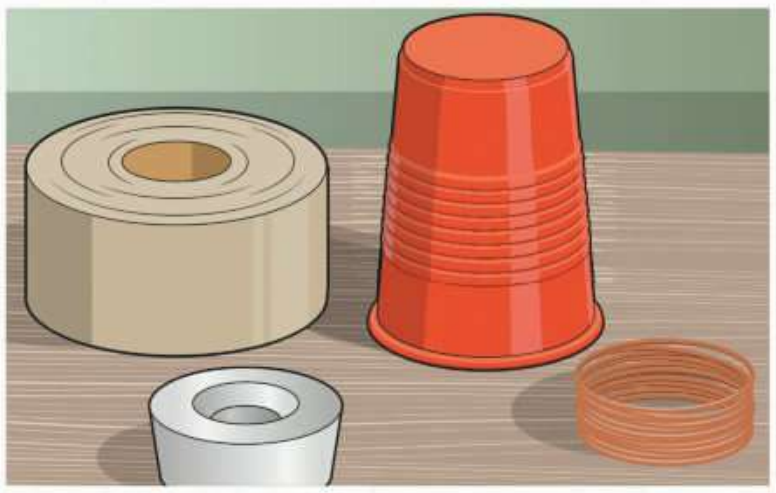
How to make your own speaker

This simple sound system will show you the physics behind your audio equipment



1 Collect your equipment

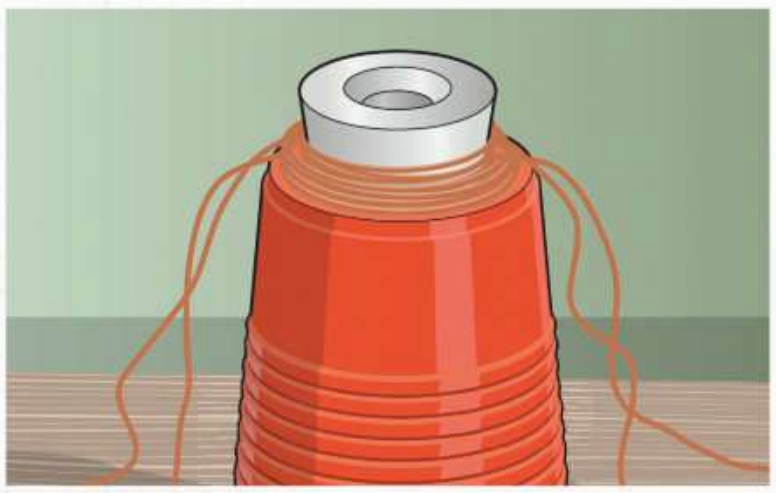
For your speaker you will need to find a copper wire, packing tape, a plastic cup and a strong magnet. These are the components for the speaker, but when finished you will need an auxiliary cord to connect it to your music.

2 Wrap the wire

Place the magnet onto the top of the upside-down cup, then wrap the wire around the magnet. Aim for seven loops, and leave plenty of wire either side, as this will be needed later. Tape the wire down and remove the magnet.

3 Double coil

Find a larger round object, such as a bottle cap, and make another coil. Using the ends of the copper wire, repeat the previous step on top and make sure there is about 30 centimetres of wire remaining on each side. Secure this with more tape.



4 Add the magnet

Take the magnet and place it within the two coils. You need the wire to be touching the magnet as much as possible, but you can adjust your components again after hearing what the music sounds like coming from your speaker to get the best result.

5 Connect the tunes

The best way to connect your music source is through an auxiliary cord. You can wrap one end of the wire around the top of the metal input and one around the bottom. If you have gator clips this process is easier, as they just need to be clamped at these two points.

6 Start the party

Now you have made your own speaker! Find and play your favourite songs and make sure the auxiliary cord is connecting your two devices. How is the quality of your sound? Using stronger magnets and tightening the coils will help you to improve the quality.

© Illustrations by Ed Crooks

SUMMARY

Your homemade speaker demonstrates how electrical signals from the wire can be converted into sound. The music on your device is stored as an electronic file, providing data on how the sound varies in pitch and volume over time. By building a speaker, you are controlling the path of this information through the copper wire.

When the electrical signal reaches the magnet, a magnetic field is created. This turns the signal into sound waves. The more coils you make around the magnet with your wire, the stronger this magnetic field becomes. Instructions in the audio file constantly change the magnetic field, creating vibrations. These vibrations move the air molecules surrounding them, which are pushed and directed by the cup to your ears.

HAD A GO? LET US KNOW!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE...

Make a water clock

Disclaimer: Neither Future Publishing nor its employees can accept any liability for any adverse effects experienced during the course of carrying out these projects or at any time after. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

INBOX
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WIN! A HAYNES MANUAL
From cars and skyscrapers to galaxies and even the Millennium Falcon, Haynes Manuals take all sorts of things apart, show the reader exactly how they work and how to repair and maintain them.
© Haynes

Source: Wiki/Unknown author
Cathal Brugha lived from 18 July 1874 to 7 July 1922

The Irish patriot
Dear **HIW,**
Who was Cathal Brugha and why was he famous?
Cathal Ò Reilly

Cathal Brugha was a prominent figure in Ireland's fight for independence, serving as a Teachta Dála, the Irish equivalent of a Member of Parliament, from 1918 to 1922. Before becoming an Irish nationalist, he went out of his way to avoid anything that wasn't from Ireland. This included not drinking any beer from England.

It is his involvement in the Irish War of Independence of 1919 to 1921 and the Irish Civil War of 1922 that he is most remembered for. During the Irish Civil War he fought passionately against the Anglo-Irish Treaty, as he wanted separate governments. It was this cause he died for. On 5 July 1922, in a weak position, Brugha ordered his men to surrender. But as he approached the enemy troops, he was shot and later died.

Letter of the month

The complexities of hearing

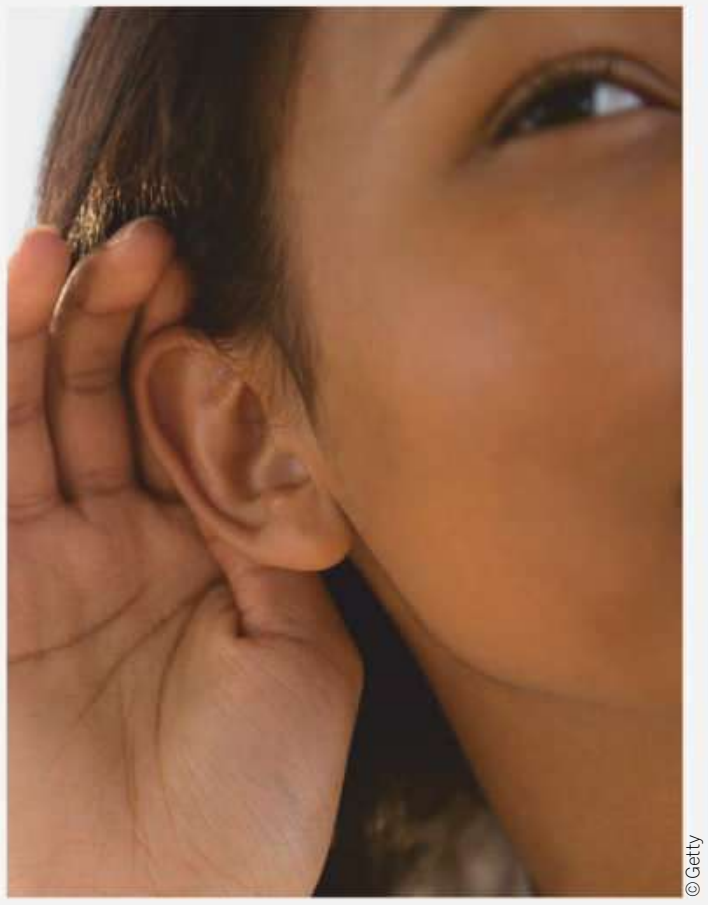
Hi **HIW,**
A long time ago I lost my hearing in my left ear due to a fall. Since then, not only have I been able to compensate for the loss, but seem to be able to hear (maybe feel, or sense) far better than ever, albeit one-sided. Why? How?

Also, when you talk in your head, is this processed by the same part of the brain that normally deals with hearing from your ears, or is it something entirely different?

Love the magazine, and I have been a long-time subscriber for a while now. I have learnt more about stuff that I never even knew existed than ever before.
Glen

Hi Glen, thanks for your message. The human brain is a fascinating organ, and it can show its skills at the most surprising times. The phenomenon you might be experiencing is due to brain plasticity. This is the brain's ability to adapt after an event which has altered its function. Many people have claimed that losing one sense has enabled their other senses to improve. The brain can remodel itself as part of a natural evolutionary process – this would have given our ancestors a better chance when competing against other people.

As for your other question, this is an internal monologue that many people have. For some these are just inner thoughts, but for others it's as if they can hear their own voice expressing their thoughts. This is believed to be connected to the auditory system. When you speak, your ears pick up the noise made, but internally another copy of your voice is being generated at the same time. Scientists speculate that your internal speech can sometimes happen even when no external sounds are being made.


© Getty
Your right ear is more responsive to speech, while your left can detect emotion better

© Getty

Winter rainbows
Dear **HIW,**
The other day I was looking out my window and noticed a beautiful rainbow. I stood and watched it until it disappeared and it got me wondering when the last time I saw one was. I don't think I've seen one in a long time. Are rainbows more common in summer than winter, or am I just outside more in the summer?
Christine Jenkins

Thanks for your letter Christine. Rainbows have a tendency to brighten up your day when you least expect it. You are right in noticing that this seems to happen more during the summer months. The weather dictates a rainbow's emergence, and during winter days it's much more likely to be cloudy. Rainbows are still common during the colder seasons, but when cloud coverage spans across a large area of the sky, it blocks any sunlight that is needed for a rainbow to appear. Also, during icy winters the clouds form ice crystals, which scatter light instead of refracting it.

Powerful protein

Dear **HIW,**

I was thinking of going vegan at some point in 2021, but I want to make sure I get all my nutrients. What are the best foods to get protein from?

Chloe Rothwell

© Getty

29 per cent of a broccoli's dry weight is protein

It's a good idea to consider how your nutrient intake can vary when changing to a new diet. Vitamin B12, Omega-3 and protein are three nutrients that you will need to make an effort to incorporate into your food. For protein, if you're introducing more vegetables into your diet, make sure you include dark-green vegetables. The best vegetables for protein include broccoli, spinach and asparagus. If you want to guarantee that the protein comes with all the amino acids your body needs, some foods to aim for are tofu, edamame beans, quinoa or a combination of rice and beans or pitta bread and hummus.

Allergies through the ages

Dear **HIW,**

I have been wondering for a while about allergies, like lactose intolerance or nut allergies, and if they have been around for a long time. Have allergies always been around or have they developed and evolved along with humans through time?

C.B.

This is a very interesting question. Through documented evidence, we know allergic reactions existed in some ancient Greeks and Romans. However, modern study of allergies only began in the 1800s, so we're unable to say for certain when they originated.

Allergy cases are increasing. Scientists think that pollution, dietary changes and less exposure to germs have played a part in our growing sensitivity to certain allergens.

© Getty

Tree nut allergies are one of the eight most common allergies

What's happening on... social media?

This month on social media we asked you: What do you think has been the best discovery or invention to come from space exploration?

@sparkellium
How much our bodies need gravity to behave normally. We need up and down!!

@aesthetically_aj
The discovery of our planet's past and what caused some of its features. By comparing Earth to other worlds we understand our own better.

@maia_h3
Finding out there are planets that could support life!

@Duttrz
I think memory foam mattresses! I couldn't sleep without mine.

@merle.haha
Views of our planet as we'd never seen it before. A new and true perspective, we are dots on a marble!

NEXT ISSUE...

Issue 148 on sale **18 FEB 2021**

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HOW IT WORKS

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UK orderline & enquiries **0330 333 1113**
Overseas order line & enquiries **+44 (0)330 333 1113**
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Printed by William Gibbons & Sons Limited
26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk
Tel: 0203 787 9001

ISSN 2041-7322

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FAST FACTS

Amazing trivia to blow your mind

1817

HMS TRINCOMALEE IS THE WORLD'S OLDEST WARSHIP THAT STILL FLOATS

8,178 METRES DEEP

THE MARIANA SNAILFISH HAS BEEN FOUND LIVING AT INCREDIBLE OCEANIC DEPTHS

23,000 BCE

CAVE PAINTINGS IN EUROPE SHOW EVIDENCE OF PREHISTORIC DRUIDS

84,000 MPH

IN 2014 THE ROSETTA SPACECRAFT'S PHILAE LANDER SUCCESSFULLY LANDED ON A SPEEDING COMET

4,250 SQUARE MILES

ICEBERG B-15 IS THE WORLD'S BIGGEST RECORDED ICEBERG – IT'S LARGER THAN THE ISLAND OF JAMAICA

SATURN'S MOON TITAN IS THE ONLY OTHER WORLD KNOWN TO HAVE LIQUID ON ITS SURFACE

POTATO PLANTS CAN GROW BERRIES THAT LOOK LIKE TOMATOES BUT ARE HIGHLY TOXIC

2,000,000,000°C

IN 2006 THE 'Z MACHINE' SET A WORLD RECORD FOR THE HOTTEST TEMPERATURE ON EARTH

ONE SQUARE MILE

CANADA'S CARCROSS DESERT, IN THE YUKON PROVINCE, IS CONSIDERED TO BE THE WORLD'S SMALLEST DESERT

1606

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1:72

McDONNELL DOUGLAS™ F/A-18A HORNET™

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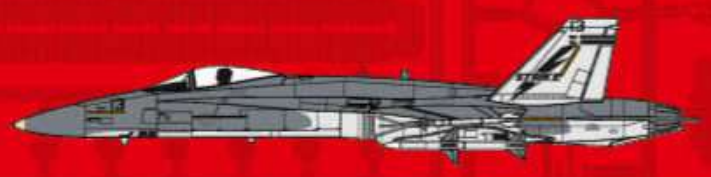
McDONNELL DOUGLAS™ F-18A HORNET™

As the US Air Force upgraded their fighter capability with the introduction of the F-15 Eagle and F-16 Fighting Falcon, the US Navy and Marine Corps were looking for a new aircraft to fulfil the dual roles of fleet defender and strike platform. The resultant aircraft was another American jet classic, the McDonnell Douglas F-18 Hornet, a distinctive looking twin engined fighter which provided naval units with a significant capability upgrade. Required to operate in the demanding environment of aircraft carriers at sea, the Hornet is an extremely tough aeroplane and has proved to be effective in the roles for which it was originally intended and flexible enough to take on additional duties. Also proving itself effective and reliable in combat, the Hornet is perhaps best known as the aircraft operated by the US Navy Flight Demonstration Squadron, the 'Blue Angels', with the team flying the F-18 since November 1986. The team are regarded as one of the premier aerobatic display teams in the world and their thrilling displays of precision flying are the highlight of any Airshow in which they perform.



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